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Gr.7 Mathematics---Mathematical Process Expectations

Problem Solving

☐ **7m1** **SQC2005** • develop, select, apply, and compare a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **7m3** **SQC2005** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **7m4** **SQC2005** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.7 Mathematics---Number Sense and Numeration

Proportional Relationships

☐ **7m27** **SQC2005** – determine, through investigation, the relationships among fractions, decimals, percents, and ratios;

Gr.7 Mathematics---Measurement

Measurement Relationships

☐ **7m37** **SQC2005** – determine, through investigation using a variety of tools (e.g., concrete materials, dynamic geometry software) and strategies, the relationship for calculating the area of a trapezoid, and generalize to develop the formula [i.e., Area = (sum of lengths of parallel sides x height) ÷ 2] (Sample problem: Determine the relationship between the area of a parallelogram and the area of a trapezoid by composing a parallelogram from congruent trapezoids.);

☐ **7m40** **SQC2005** – determine, through investigation using a variety of tools and strategies (e.g., decomposing right prisms; stacking congruent layers of concrete materials to form a right prism), the relationship between the height, the area of the base, and the volume of right prisms with simple polygonal bases (e.g., parallelograms, trapezoids), and generalize to develop the formula (i.e., Volume = area of base x height) (Sample problem: Decompose right prisms with simple polygonal bases into triangular prisms and rectangular prisms. For each prism, record the area of the base, the height, and the volume on a chart. Identify relationships.);

☐ **7m41** **SQC2005** – determine, through investigation using a variety of tools (e.g., nets, concrete materials, dynamic geometry software, Polydrons), the surface area of right prisms;

Gr.7 Mathematics---Geometry and Spatial Sense

Geometric Properties

☐ **7m47** **SQC2005** – sort and classify triangles and quadrilaterals by geometric properties related to symmetry, angles, and sides, through investigation using a variety of tools (e.g., geoboard, dynamic geometry software) and strategies (e.g., using charts, using Venn diagrams) (Sample problem: Investigate whether dilatations change the geometric properties of triangles and quadrilaterals.);

☐ **7m49** **SQC2005** – investigate, using concrete materials, the angles between the faces of a prism, and identify right prisms (Sample problem: Identify the perpendicular faces in a set of right prisms.).

Geometric Relationships

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within: **Mathematics**

☐ **7m50** **SQC2005** – identify, through investigation, the minimum side and angle information (i.e., side-side-side; side-angle-side; angle-sideangle) needed to describe a unique triangle (e.g., "I can draw many triangles if I'm only told the length of one side, but there's only one triangle I can draw if you tell me the lengths of all three sides.");

☐ **7m51** **SQC2005** – determine, through investigation using a variety of tools (e.g., dynamic geometry software, concrete materials, geoboard), relationships among area, perimeter, corresponding side lengths, and corresponding angles of congruent shapes (Sample problem: Do you agree with the conjecture that triangles with the same area must be congruent? Justify your reasoning.);

Location and Movement

☐ **7m55** **SQC2005** – identify, perform, and describe dilatations (i.e., enlargements and reductions), through investigation using a variety of tools (e.g., dynamic geometry software, geoboard, pattern blocks, grid paper);

☐ **7m57** **SQC2005** – determine, through investigation using a variety of tools (e.g., pattern blocks, Polydrons, grid paper, tiling software, dynamic geometry software, concrete materials), polygons or combinations of polygons that tile a plane, and describe the transformation(s) involved.

Gr.7 Mathematics---Patterning and Algebra

Patterns and Relationships

☐ **7m61** **SQC2005** – make predictions about linear growing patterns, through investigation with concrete materials (Sample problem: Investigate the surface area of towers made from a single column of connecting cubes, and predict the surface area of a tower that is 50 cubes high. Explain your reasoning.);

☐ **7m63** **SQC2005** – compare pattern rules that generate a pattern by adding or subtracting a constant, or multiplying or dividing by a constant, to get the next term (e.g., for 1, 3, 5, 7, 9, …, the pattern rule is "start at 1 and add 2 to each term to get the next term") with pattern rules that use the term number to describe the general term (e.g., for 1, 3, 5, 7, 9, …, the pattern rule is "double the term number and subtract 1", which can be written algebraically as 2 x n – 1) (Sample problem: For the pattern 1, 3, 5, 7, 9, …, investigate and compare different ways of finding the 50th term.).

Variables, Expressions, and Equations

☐ **7m64** **SQC2005** – model real-life relationships involving constant rates where the initial condition starts at 0 (e.g., speed, heart rate, billing rate), through investigation using tables of values and graphs (Sample problem: Create a table of values and graph the relationship between distance and time for a car travelling at a constant speed of 40 km/h. At that speed, how far would the car travel in 3.5 h? How many hours would it take to travel 220 km?);

Gr.7 Mathematics---Data Management and Probability

Data Relationships

☐ **7m79** **SQC2005** – identify, through investigation, graphs that present data in misleading ways (e.g., line graphs that exaggerate change by starting the vertical axis at a point greater than zero);

☐ **7m80** **SQC2005** – determine, through investigation, the effect on a measure of central tendency (i.e., mean, median, and mode) of adding or removing a value or values (e.g., changing the value of an outlier may have a significant effect on the mean but no effect on the median) (Sample problem: Use a set of data whose distribution across its range looks symmetrical, and change some of the values so that the distribution no longer looks symmetrical. Does the change affect the median more than the mean? Explain your thinking.);

Gr.8 Mathematics---Mathematical Process Expectations

Problem Solving

☐ **8m1** **SQC2005** • develop, select, apply, and compare a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

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Reflecting

- ☐ **8m3** **SQC2005** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

- ☐ **8m4** **SQC2005** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.8 Mathematics---Measurement

Measurement Relationships

- ☐ **8m35** **SQC2005** – determine, through investigation using a variety of tools (e.g., cans and string, dynamic geometry software) and strategies, the relationships for calculating the circumference and the area of a circle, and generalize to develop the formulas [i.e., Circumference of a circle = π x diameter; Area of a circle = π x (radius)^2] (Sample problem: Use string to measure the circumferences and the diameters of a variety of cylindrical cans, and investigate the ratio of the circumference to the diameter.);
- ☐ **8m37** **SQC2005** – determine, through investigation using a variety of tools and strategies (e.g., generalizing from the volume relationship for right prisms, and verifying using the capacity of thin-walled cylindrical containers), the relationship between the area of the base and height and the volume of a cylinder, and generalize to develop the formula (i.e., Volume = area of base x height);
- ☐ **8m38** **SQC2005** – determine, through investigation using concrete materials, the surface area of a cylinder (Sample problem: Use the label and the plastic lid from a cylindrical container to help determine its surface area.);

Gr.8 Mathematics---Geometry and Spatial Sense

Geometric Properties

- ☐ **8m43** **SQC2005** – sort and classify quadrilaterals by geometric properties, including those based on diagonals, through investigation using a variety of tools (e.g., concrete materials, dynamic geometry software) (Sample problem: Which quadrilaterals have diagonals that bisect each other perpendicularly?);
- ☐ **8m45** **SQC2005** – investigate and describe applications of geometric properties (e.g., properties of triangles, quadrilaterals, and circles) in the real world.

Geometric Relationships

- ☐ **8m46** **SQC2005** – determine, through investigation using a variety of tools (e.g., dynamic geometry software, concrete materials, geoboard), relationships among area, perimeter, corresponding side lengths, and corresponding angles of similar shapes (Sample problem: Construct three similar rectangles, using grid paper or a geoboard, and compare the perimeters and areas of the rectangles.);
- ☐ **8m47** **SQC2005** – determine, through investigation using a variety of tools (e.g., dynamic geometry software, concrete materials, protractor) and strategies (e.g., paper folding), the angle relationships for intersecting lines and for parallel lines and transversals, and the sum of the angles of a triangle;
- ☐ **8m49** **SQC2005** – determine the Pythagorean relationship, through investigation using a variety of tools (e.g., dynamic geometry software; paper and scissors; geoboard) and strategies;
- ☐ **8m51** **SQC2005** – determine, through investigation using concrete materials, the relationship between the numbers of faces, edges, and vertices of a polyhedron (i.e., number of faces + number of vertices = number of edges + 2) (Sample problem: Use Polydrons and/or paper nets to construct the five Platonic solids [i.e., tetrahedron, cube, octahedron, dodecahedron, icosahedron], and compare the sum of the numbers of faces and vertices to the number of edges for each solid.).

Location and Movement

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☐ **8m53** **SQC2005** – identify, through investigation, real-world movements that are translations, reflections, and rotations.

Gr.8 Mathematics---Patterning and Algebra

Patterns and Relationships

☐ **8m56** **SQC2005** – represent, through investigation with concrete materials, the general term of a linear pattern, using one or more algebraic expressions (e.g., "Using toothpicks, I noticed that 1 square needs 4 toothpicks, 2 connected squares need 7 toothpicks, and 3 connected squares need 10 toothpicks. I think that for n connected squares I will need 4 + 3(n – 1) toothpicks, because the number of toothpicks keeps going up by 3 and I started with 4 toothpicks. Or, if I think of starting with 1 toothpick and adding 3 toothpicks at a time, the pattern can be represented as 1 + 3n.");

Variables, Expressions, and Equations

☐ **8m60** **SQC2005** – model linear relationships using tables of values, graphs, and equations (e.g., the sequence 2, 3, 4, 5, 6, … can be represented by the equation t = n + 1, where n represents the term number and t represents the term), through investigation using a variety of tools (e.g., algebra tiles, pattern blocks, connecting cubes, base ten materials) (Sample problem: Leah put $350 in a bank certificate that pays 4% simple interest each year. Make a table of values to show how much the bank certificate is worth after five years, using base ten materials to help you. Represent the relationship using an equation.);

Gr.8 Mathematics---Data Management and Probability

Data Relationships

☐ **8m74** **SQC2005** – determine, through investigation, the appropriate measure of central tendency (i.e., mean, median, or mode) needed to compare sets of data (e.g., in hockey, compare heights or masses of players on defence with that of forwards);

Probability

☐ **8m80** **SQC2005** – compare, through investigation, the theoretical probability of an event (i.e., the ratio of the number of ways a favourable outcome can occur compared to the total number of possible outcomes) with experimental probability, and explain why they might differ (Sample problem:Toss a fair coin 10 times, record the results, and explain why you might not get the predicted result of 5 heads and 5 tails.);

☐ **8m81** **SQC2005** – determine, through investigation, the tendency of experimental probability to approach theoretical probability as the number of trials in an experiment increases, using class-generated data and technology-based simulation models (Sample problem: Compare the theoretical probability of getting a 6 when tossing a number cube with the experimental probabilities obtained after tossing a number cube once, 10 times, 100 times, and 1000 times.);

Gr.12 Foundations for College Mathematics---Mathematics Process Specific Expectations MAP 4C

Problem Solving

☐ **MPS.01** **CR2007** • develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **MPS.03** **CR2007** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **MPS.04** **CR2007** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

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Gr.12 Foundations for College Mathematics---A. MATHEMATICAL MODELS MAP 4C

1. Solving Exponential Equations

- ☐ **MM1.01** **CR2007** 1.1 determine, through investigation (e.g., by expanding terms and patterning), the exponent laws for multiplying and dividing algebraic expressions involving exponents [e.g., $(x^3)(x^2)$, x^3x^5] and the exponent law for simplifying algebraic expressions involving a power of a power [e.g. $(x^6y^3)^2$]
- ☐ **MM1.03** **CR2007** 1.3 determine, through investigation using a variety of tools (e.g., calculator, paper and pencil, graphing technology) and strategies (e.g., patterning; finding values from a graph; interpreting the exponent laws), the value of a power with a rational exponent (i.e., $x^{m/n}$, where x > 0 and m and n are integers) Sample problem: The exponent laws suggest that $4^{1/2} \times 4^{1/2} = 4^1$. What value would you assign to $4^{1/2}$? What value would you assign to $27^{1/3}$? Explain your reasoning. Extend your reasoning to make a generalization about the meaning of $x^{1/n}$, where x > 0 and n is a natural number.

2. Modelling Graphically

- ☐ **MM2.05** **CR2007** 2.5 compare, through investigation with technology, the graphs of pairs of relations (i.e., linear, quadratic, exponential) by describing the initial conditions and the behaviour of the rates of change (e.g., compare the graphs of amount versus time for equal initial deposits in simple interest and compound interest accounts) Sample problem: In two colonies of bacteria, the population doubles every hour. The initial population of one colony is twice the initial population of the other. How do the graphs of population versus time compare for the two colonies? How would the graphs change if the population tripled every hour, instead of doubling?

Gr.12 Foundations for College Mathematics---B. PERSONAL FINANCE MAP 4C

1. Understanding Annuities

- ☐ **PE1.02** **CR2007** 1.2 determine, through investigation using technology (e.g., the TVM Solver on a graphing calculator; online tools), the effects of changing the conditions (i.e., the payments, the frequency of the payments, the interest rate, the compounding period) of an ordinary simple annuity (i.e., an annuity in which payments are made at the end of each period, and compounding and payment periods are the same) (e.g., long-term savings plans, loans) Sample problem: Given an ordinary simple annuity with semi-annual deposits of $1000, earning 6% interest per year compounded semi-annually, over a 20-year term, which of the following results in the greatest return: doubling the payments, doubling the interest rate, doubling the frequency of the payments and the compounding, or doubling the payment and compounding period?
- ☐ **PE1.04** **CR2007** 1.4 demonstrate, through investigation using technology (e.g., a TVM Solver), the advantages of starting deposits earlier when investing in annuities used as long-term savings plans Sample problem: If you want to have a million dollars at age 65, how much would you have to contribute monthly into an investment that pays 7% per annum, compounded monthly, beginning at age 20? At age 35? At age 50?
- ☐ **PE1.08** **CR2007** 1.8 determine, through investigation using technology (e.g., TVM Solver, online tools, financial software), the effects of varying payment periods, regular payments, and interest rates on the length of time needed to pay off a mortgage and on the total interest paid Sample problem: Calculate the interest saved on a $100 000 mortgage with monthly payments, at 6% per annum compounded semi-annually, when it is amortized over 20 years instead of 25 years.

3. Designing Budgets

- ☐ **PE3.04** **CR2007** 3.4 identify and describe the factors to be considered in determining the affordability of accommodation in the local community (e.g., income, long-term savings, number of dependants, non-discretionary expenses), and consider the affordability of accommodation under given circumstances Sample problem: Determine, through investigation, if it is possible to change from renting to owning accommodation in your community in five years if you currently earn $30 000 per year, pay $900 per month in rent, and have savings of $20 000.

Gr.12 Foundations for College Mathematics---C. GEOMETRY AND TRIGONOMETRY MAP 4C

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within: **Mathematics**

2. Investigating Optimal Dimensions

- ☐ **GT2.01** **CR2007** 2.1 recognize, through investigation using a variety of tools (e.g., calculators; dynamic geometry software; manipulatives such as tiles, geoboards, toothpicks) and strategies (e.g., modelling; making a table of values; graphing), and explain the significance of optimal perimeter, area, surface area, and volume in various applications (e.g., the minimum amount of packaging material, the relationship between surface area and heat loss) Sample problem: You are building a deck attached to the second floor of a cottage, as shown below. Investigate how perimeter varies with different dimensions if you build the deck using exactly 48 1-m x 1-m decking sections, and how area varies if you use exactly 30 m of deck railing. Note: the entire outside edge of the deck will be railed. (omitted graph from page 142)
- ☐ **GT2.02** **CR2007** 2.2 determine, through investigation using a variety of tools (e.g., calculators, dynamic geometry software, manipulatives) and strategies (e.g., modelling; making a table of values; graphing), the optimal dimensions of a two-dimensional shape in metric or imperial units for a given constraint (e.g., the dimensions that give the minimum perimeter for a given area) Sample problem: You are constructing a rectangular deck against your house. You will use 32 ft of railing and will leave a 4-ft gap in the railing for access to stairs. Determine the dimensions that will maximize the area of the deck.
- ☐ **GT2.03** **CR2007** 2.3 determine, through investigation using a variety of tools and strategies (e.g., modelling with manipulatives; making a table of values; graphing), the optimal dimensions of a right rectangular prism, a right triangular prism, and a right cylinder in metric or imperial units for a given constraint (e.g., the dimensions that give the maximum volume for a given surface area) Sample problem: Use a table of values and a graph to investigate the dimensions of a rectangular prism, a triangular prism, and a cylinder that each have a volume of 64 cm3 and the minimum surface area

3. Solving Problems Involving Trigonometry

- ☐ **GT3.02** **CR2007** 3.2 make connections between primary trigonometric ratios (i.e., sine, cosine, tangent) of obtuse angles and of acute angles, through investigation using a variety of tools and strategies (e.g., using dynamic geometry software to identify an obtuse angle with the same sine as a given acute angle; using a circular geoboard to compare congruent triangles; using a scientific calculator to compare trigonometric ratios for supplementary angles)

Gr.11 Foundations for College Mathematics---Mathematics Process Specific Expectations MBF 3C

Problem Solving

- ☐ **MPS.01** **CR2006** • develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

- ☐ **MPS.03** **CR2006** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

- ☐ **MPS.04** **CR2006** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.11 Foundations for College Mathematics---Mathematical Models MBF 3C

Connecting Graphs and Equations of Quadratic Relations

- ☐ **MM1.03** **CR2006** – determine, through investigation using technology, and describe the roles of a, h, and k in quadratic relations of the form $y = a(x - h)^2 + k$ in terms of transformations on the graph of $y = x^2$ (i.e., translations; reflections in the x-axis; vertical stretches and compressions) [Sample problem: Investigate the graph $y = 3(x - h)^2 + 5$ for various values of h, using technology, and describe the effects of changing h in terms of a transformation.];

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- ☐ **MM1.08** **CR2006** – determine, through investigation, and describe the connection between the factors of a quadratic expression and the x-intercepts of the graph of the corresponding quadratic relation (Sample problem: Investigate the relationship between the factored form of $3x^2 + 15x + 12$ and the x-intercepts of $y = 3x^2 + 15x + 12$.);

Connecting Graphs and Equations of Exponential Relations

- ☐ **MM2.01** **CR2006** – determine, through investigation using a variety of tools and strategies (e.g., graphing with technology; looking for patterns in tables of values), and describe the meaning of negative exponents and of zero as an exponent;
- ☐ **MM2.03** **CR2006** – determine, through investigation (e.g., by patterning with and without a calculator), the exponent rules for multiplying and dividing numerical expressions involving exponents [e.g., $(1/2)^3 \times (1/2)^2$], and the exponent rule for simplifying numerical expressions involving a power of a power [e.g., $(53)^2$];

Solving Problems Involving Exponential Relations

- ☐ **MM3.01** **CR2006** – collect data that can be modelled as an exponential relation, through investigation with and without technology, from primary sources, using a variety of tools (e.g., concrete materials such as number cubes, coins; measurement tools such as electronic probes), or from secondary sources (e.g.,websites such as Statistics Canada, E-STAT), and graph the data (Sample problem: Collect data and graph the cooling curve representing the relationship between temperature and time for hot water cooling in a porcelain mug. Predict the shape of the cooling curve when hot water cools in an insulated mug.Test your prediction.);

Gr.11 Foundations for College Mathematics---Personal Finance MBF 3C

Solving Problems Involving Compound Interest

- ☐ **PF1.01** **CR2006** – determine, through investigation using technology, the compound interest for a given investment, using repeated calculations of simple interest, and compare, using a table of values and graphs, the simple and compound interest earned for a given principal (i.e., investment) and a fixed interest rate over time (Sample problem: Compare, using tables of values and graphs, the amounts after each of the first five years for a $1000 investment at 5% simple interest per annum and a $1000 investment at 5% interest per annum, compounded annually.);
- ☐ **PF1.02** **CR2006** – determine, through investigation (e.g., using spreadsheets and graphs), and describe the relationship between compound interest and exponential growth;
- ☐ **PF1.06** **CR2006** – determine, through investigation using technology (e.g., a TVM Solver in a graphing calculator or on a website), the effect on the future value of a compound interest investment or loan of changing the total length of time, the interest rate, or the compounding period (Sample problem: Investigate whether doubling the interest rate will halve the time it takes for an investment to double.).

Comparing Financial Services

- ☐ **PF2.04** **CR2006** – gather, interpret, and compare information about current credit card interest rates and regulations, and determine, through investigation using technology, the effects of delayed payments on a credit card balance;

Owning and Operating a Vehicle

- ☐ **PF3.01** **CR2006** – gather and interpret information about the procedures and costs involved in insuring a vehicle (e.g., car, motorcycle, snowmobile) and the factors affecting insurance rates (e.g., gender, age, driving record, model of vehicle, use of vehicle), and compare the insurance costs for different categories of drivers and for different vehicles (Sample problem: Use automobile insurance websites to investigate the degree to which the type of car and the age and gender of the driver affect insurance rates.);

Gr.11 Foundations for College Mathematics---Geometry and Trigonometry MBF 3C

Representing Two-Dimensional Shapes and Three-Dimensional Figures

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☐ **GT1.01** **CR2006** – identify real-world applications of geometric shapes and figures, through investigation (e.g., by importing digital photos into dynamic geometry software), in a variety of contexts (e.g., product design, architecture, fashion), and explain these applications (e.g., one reason that sewer covers are round is to prevent them from falling into the sewer during removal and replacement) (Sample problem: Explain why rectangular prisms are used for packaging many products.);

Applying the Sine Law and the Cosine Law in Acute Triangles

☐ **GT2.02** **CR2006** – verify, through investigation using technology (e.g., dynamic geometry software, spreadsheet), the sine law and the cosine law (e.g., compare, using dynamic geometry software, the ratios a/sinA , b/sinB , and c/sinC in triangle ABC while dragging one of the vertices);

Gr.11 Foundations for College Mathematics---Data Management MBF 3C

Applying Probability

☐ **DM2.04** **CR2006** – compare, through investigation, the theoretical probability of an event with the experimental probability, and explain why they might differ (Sample problem: If you toss 10 coins repeatedly, explain why 5 heads are unlikely to result from every toss.);

☐ **DM2.05** **CR2006** – determine, through investigation using class-generated data and technology-based simulation models (e.g., using a random-number generator on a spreadsheet or on a graphing calculator), the tendency of experimental probability to approach theoretical probability as the number of trials in an experiment increases (e.g.,?If I simulate tossing a coin 1000 times using technology, the experimental probability that I calculate for tossing tails is likely to be closer to the theoretical probability than if I only simulate tossing the coin 10 times?) (Sample problem: Calculate the theoretical probability of rolling a 2 on a number cube. Simulate rolling a number cube, and use the simulation to calculate the experimental probability of rolling a 2 after 10, 20, 30, ..., 200 trials. Graph the experimental probability versus the number of trials, and describe any trend.);

Gr.11 Functions and Applications---Mathematics Process Specific Expectations MCF 3M

Problem Solving

☐ **MPS.01** **CR2006** • develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **MPS.03** **CR2006** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **MPS.04** **CR2006** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.11 Functions and Applications---Quadratic Functions MCF 3M

Solving Quadratic Equations

☐ **QF1.05** **CR2006** – determine, through investigation, and describe the connection between the factors used in solving a quadratic equation and the x-intercepts of the corresponding quadratic relation (Sample problem: The profit, P, of a video company, in thousands of dollars, is given by $P = -5x^2 + 550x - 5000$, where x is the amount spent on advertising, in thousands of dollars. Determine, by factoring and by graphing, the amount spent on advertising that will result in a profit of $0. Describe the connection between the two strategies.);

Connecting Graphs and Equations of Quadratic Functions

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within: **Mathematics**

- ☐ **QF2.01 CR2006** – explain the meaning of the term function, and distinguish a function from a relation that is not a function, through investigation of linear and quadratic relations using a variety of representations (i.e., tables of values, mapping diagrams, graphs, function machines, equations) and strategies (e.g., using the vertical line test) (Sample problem: Investigate, using numeric and graphical representations, whether the relation $x = y^2$ is a function, and justify your reasoning.);
- ☐ **QF2.03 CR2006** – explain the meanings of the terms domain and range, through investigation using numeric, graphical, and algebraic representations of linear and quadratic functions, and describe the domain and range of a function appropriately (e.g., for $y = x^2 + 1$, the domain is the set of real numbers, and the range is $y \geq 1$);
- ☐ **QF2.05 CR2006** – determine, through investigation using technology, and describe the roles of a, h,and k in quadratic functions of the form $f(x) = a(x- h)^2 + k$ in terms of transformations on the graph of $f(x) = x^2$ (i.e., translations; reflections in the x-axis; vertical stretches and compressions) [Sample problem: Investigate the graph $f(x) = 3(x- h)^2 + 5$ for various values of h, using technology, and describe the effects of changing h in terms of a transformation.];

Solving Problems Involving Quadratic Functions

- ☐ **QF3.01 CR2006** – collect data that can be modelled as a quadratic function, through investigation with and without technology, from primary sources, using a variety of tools (e.g., concrete materials; measurement tools such as measuring tapes, electronic probes, motion sensors), or from secondary sources (e.g., websites such as Statistics Canada, E-STAT), and graph the data (Sample problem: When a 3 x 3 x 3 cube made up of 1 x 1 x 1 cubes is dipped into red paint, 6 of the smaller cubes will have 1 face painted. Investigate the number of smaller cubes with 1 face painted as a function of the edge length of the larger cube, and graph the function.);
- ☐ **QF3.02 CR2006** – determine, through investigation using a variety of strategies (e.g., applying properties of quadratic functions such as the x-intercepts and the vertex; using transformations), the equation of the quadratic function that best models a suitable data set graphed on a scatter plot, and compare this equation to the equation of a curve of best fit generated with technology (e.g., graphing software, graphing calculator);

Gr.11 Functions and Applications---Exponential Functions MCF 3M

Connecting Graphs and Equations Exponential Functions

- ☐ **EF1.01 CR2006** – determine, through investigation using avariety of tools (e.g., calculator, paper and pencil, graphing technology) and strategies (e.g., patterning; finding values from a graph; interpreting the exponent laws), the value of a power with a rational exponent (i.e.,x,where x>0 and m and n are integers) (Sample problem:The exponent laws suggest that $4^{1/2} \times 4^{1/2} = 4^1$. What value would you assign to $4^{1/2}$? What value would you assign to $27^{1/3}$? Explain your reasoning. Extend your reasoning to make a generalization about the meaning of $x^{1/n}$, where x > 0 and n is a natural number.);
- ☐ **EF1.04 CR2006** – determine, through investigation, and describekey properties relating to domain and range, intercepts, increasing/decreasing intervals, and asymptotes (e.g., the domain is the set of real numbers; the range is the set of positive real numbers; the function either increases or decreases throughout its domain) for exponential functions represented in avariety of ways [e.g., tables of values, mapping diagrams, graphs, equations of the form $f(x) = ax(a > 0, a \neq 1)$, function machines] [Sample problem:Graph $f(x) = 2^x$, $g(x) = 3^x$, and $h(x) = 0.5^x$ on the same set of axes. Make comparisons between the graphs, and explain the relationship between the y-intercepts.];
- ☐ **EF1.05 CR2006** – determine, through investigation (e.g., by patterning with and without a calculator), the exponent rules for multiplying and dividing numerical expressions involving exponents [e.g., $(1/2)^3 \times (1/2)^2$], and the exponent rule for simplifying numerical expressions involving a power of a power [e.g.,$(5^3)^2$], and use the rules to simplify numerical expressions containing integer exponents [e.g., $(2^3)\ (2^5) = 28$];

Solving Problems Involving Exponential Functions

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within: **Gr.7, Gr.8, Gr.9, Gr.10, Gr.11, Gr.12**
within: **Mathematics**

- ☐ **EF2.01** **CR2006** – collect data that can be modelled as an exponential function, through investigation with and without technology, from primary sources, using a variety of tools (e.g., concrete materials such as number cubes, coins; measurement tools such as electronic probes), or from secondary sources (e.g., websites such as Statistics Canada, E-STAT), and graph the data (Sample problem: Collect data and graph the cooling curve representing the relationship between temperature and time for hot water cooling in a porcelain mug. Predict the shape of the cooling curve when hot water cools in an insulated mug. Test your prediction.);

Solving Financial Problems Involving Exponential Functions

- ☐ **EF3.03** **CR2006** – determine, through investigation (e.g., using spreadsheets and graphs), that compound interest is an example of exponential growth [e.g., the formulas for compound interest, $A = P(1 + i)^n$, and present value, $PV = A(1 + i)^{-n}$, are exponential functions, where the number of compounding periods, n, varies] [Sample problem: Describe an investment that could be represented by the function $f(x) = 500(1.01)^x$];
- ☐ **EF3.05** **CR2006** – explain the meaning of the term annuity, through investigation of numerical and graphical representations using technology;
- ☐ **EF3.06** **CR2006** – determine, through investigation using technology (e.g., the TVM Solver in a graphing calculator; online tools), the effects of changing the conditions (i.e., the payments, the frequency of the payments, the interest rate, the compounding period) of ordinary annuities in situations where the compounding period and the payment period are the same (e.g., long-term savings plans, loans) (Sample problem: Compare the amounts at age 65 that would result from making an annual deposit of $1000 starting at age 20, or from making an annual deposit of $3000 starting at age 50, to an RRSP that earns 6% interest per annum, compounded annually. What is the total of the deposits in each situation?);

Gr.11 Functions and Applications---Trigonometric Functions MCF 3M

Applying the Sine Law and the Cosine Law in Acute Triangles

- ☐ **TF1.03** **CR2006** – verify, through investigation using technology (e.g., dynamic geometry software, spreadsheet), the sine law and the cosine law (e.g., compare, using dynamic geometry software, the ratios a/sin A, b/sinB, and c/sinC in triangle ABC while dragging one of the vertices);

Connecting Graphs and Equations of Sine Functions

- ☐ **TF2.05** **CR2006** – make connections, through investigation with technology, between changes in a real-world situation that can be modelled using a periodic function and transformations of the corresponding graph (e.g., investigating the connection between variables for a swimmer swimming lengths of a pool and transformations of the graph of distance from the starting point versus time) (Sample problem: Generate a sine curve by walking a circle of two-metre diameter in front of a motion sensor. Describe how the following changes in the motion change the graph: starting at a different point on the circle; starting a greater distance from the motion sensor; changing direction; increasing the radius of the circle; and increasing the speed);
- ☐ **TF2.06** **CR2006** – determine, through investigation using technology, and describe the roles of the parameters a, c,and d in functions in the form f(x) = a sinx, f(x) = sinx + c, and f(x) = sin(x - d) in terms of transformations on the graph of f(x) = sinx with angles expressed in degrees (i.e., translations; reflections in the x-axis; vertical stretches and compressions);

Solving Problems Involving Sine Functions

- ☐ **TF3.01** **CR2006** – collect data that can be modelled as a sine function (e.g., voltage in an AC circuit, sound waves), through investigation with and without technology, from primary sources, using a variety of tools (e.g., concrete materials; measurement tools such as motion sensors), or from secondary sources (e.g., websites such as Statistics Canada, E-STAT), and graph the data (Sample problem: Measure and record distance-time data for a swinging pendulum, using a motion sensor or other measurement tools, and graph the data.);

Gr.11 Functions---Mathematics Process Specific Expectations MCR 3U

Problem Solving

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within: **Mathematics**

☐ **MPS.01** **CR2006** • develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **MPS.03** **CR2006** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **MPS.04** **CR2006** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.11 Functions---Characteristics of Functions MCR 3U

Representing Functions

☐ **CF1.01** **CR2006** – explain the meaning of the term function, and distinguish a function from a relation that is not a function, through investigation of linear and quadratic relations using a variety of representations (i.e., tables of values, mapping diagrams, graphs, function machines, equations) and strategies (e.g., identifying a one-to-one or many-to-one mapping; using the vertical line test) (Sample problem: Investigate, using numeric and graphical representations, whether the relation $x = y^2$ is a function, and justify your reasoning.);

☐ **CF1.03** **CR2006** – explain the meanings of the terms domain and range, through investigation using numeric, graphical, and algebraic representations of the functions $f(x) = x$, $f(x) = x^2$, $f(x) = \sqrt{x}$,and $f(x) = 1/x$; describe the x domain and range of a function appropriately (e.g., for $y = x^2 + 1$, the domain is the set of real numbers, and the range is $y \leq 1$); and explain any restrictions on the domain and range in contexts arising from real-world applications (Sample problem: A quadratic function represents the relationship between the height of a ball and the time elapsed since the ball was thrown. What physical factors will restrict the domain and range of the quadratic function?);

☐ **CF1.05** **CR2006** – determine the numeric or graphical representation of the inverse of a linear or quadratic function, given the numeric, graphical, or algebraic representation of the function, and make connections, through investigation using a variety of tools (e.g., graphing technology, Mira, tracing paper), between the graph of a function and the graph of its inverse (e.g., the graph of the inverse is the reflection of the graph of the function in the line $y = x$) (Sample problem: Given a graph and a table of values representing population over time, produce a table of values for the inverse and graph the inverse on a new set of axes.);

☐ **CF1.06** **CR2006** – determine, through investigation, the relationship between the domain and range of a function and the domain and range of the inverse relation, and determine whether or not the inverse relation is a function [Sample problem: Given the graph of $f(x) = x^2$, graph the inverse relation. Compare the domain and range of the function with the domain and range of the inverse relation, and investigate connections to the domain and range of the functions $g(x) = \sqrt{x}$,and $h(x) = -\sqrt{x}$.];

☐ **CF1.07** **CR2006** – determine, using function notation when appropriate, the algebraic representation of the inverse of a linear or quadratic function, given the algebraic representation of the function [e.g., $f(x) = (x - 2)^2 - 5$],and make connections, through investigation using a variety of tools (e.g., graphing technology, Mira, tracing paper), between the algebraic representations of a function and its inverse (e.g., the inverse of a linear function involves applying the inverse operations in the reverse order) (Sample problem: Given the equations of several linear functions, graph the functions and their inverses, determine the equations of the inverses, and look for patterns that connect the equation of each linear function with the equation of the inverse.);

☐ **CF1.08** **CR2006** – determine, through investigation using technology, and describe the roles of the parameters a, k, d,and c in functions of the form $y = af(k(x - d)) + c$ in terms of transformations on the graphs of $f(x) = x$, $f(x) = x^2$, $f(x) = \sqrt{x}$,and $f(x) = 1/x$ (i.e., translations; reflections in the axes; vertical and horizontal stretches and compressions) [Sample problem: Investigate the graph $f(x) = 3(x - d)^2 + 5$ for various values of d, using technology, and describe the effects of changing d in terms of a transformation.];

Solving Problems Involving Quadratic Functions

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- ☐ **CF2.01 CR2006** – determine the number of zeros (i.e., x-intercepts) of a quadratic function, using a variety of strategies (e.g., inspecting graphs; factoring; calculating the discriminant) (Sample problem: Investigate, using graphing technology and algebraic techniques, the transformations that affect the number of zeros for a given quadratic function.);
- ☐ **CF2.04 CR2006** – determine, through investigation, the transformational relationship among the family of quadratic functions that have the same zeros, and determine the algebraic representation of a quadratic function, given the real roots of the corresponding quadratic equation and a point on the function [Sample problem: Determine the equation of the quadratic function that passes through (2, 5) if the roots of the corresponding quadratic equation are $1 + \sqrt{5}$ and $1 - \sqrt{5}$.];
- ☐ **CF2.05 CR2006** – solve problems involving the intersection of a linear function and a quadratic function graphically and algebraically (e.g., determining the time when two identical cylindrical water tanks contain equal volumes of water, if one tank is being filled at a constant rate and the other is being emptied through a hole in the bottom) [Sample problem: Determine, through investigation, the equations of the lines that have a slope of 2 and that intersect the quadratic function f (x) = x(6 - x) once; twice; never.].

Determining Equivalent Algebraic Expressions*

- ☐ **CF3.02 CR2006** – verify, through investigation with and without technology, that $\sqrt{ab} = \sqrt{a} \times \sqrt{b}$, a = 0, b = 0, and use this relationship to simplify radicals (e.g., $\sqrt{24}$) and radical expressions obtained by adding, subtracting, and multiplying [e.g., $(2 + \sqrt{6})(3 - \sqrt{12})$].

Gr.11 Functions---Exponential Functions MCR 3U

Representing Exponential Functions

- ☐ **EF1.02 CR2006** – determine, through investigation using a variety of tools (e.g., calculator, paper and pencil, graphing technology) and strategies (e.g., patterning;finding values from a graph;interpreting the exponent laws), the value of a power with a rational exponent (i.e., x, where x >0 and m and n are integers) (Sample problem:The exponent laws suggest that $4^{1/2} \times 4^{1/2} = 4^1$ .What value would you assign to $4^{1/2}$? What value would you assign to $27^{1/3}$? Explain your reasoning. Extend your reasoning to make a generalization about the meaning of $x^{1/n}$,where x > 0 and n is a natural number.);
- ☐ **EF1.04 CR2006** – determine, through investigation,and describe key properties relating to domain and range, intercepts, increasing/decreasing intervals, and asymptotes (e.g., the domainis the set of real numbers; the range is the set of positive real numbers; the function either increases or decreases throughout its domain) for exponential functions represented in a variety of ways [e.g., tables of values, mapping diagrams, graphs,equations of the form $f(x) = a^x (a > 0, a \neq 1)$, function machines] [Sample problem:Graph $f(x) = 2^x$, $g(x) = 3^x$, and $h(x) = 0.5^x$ on the same set of axes. Make comparisons between the graphs,and explain the relationship between the y-intercepts.].

Connecting Graphs and Equations of Exponential Functions

- ☐ **EF2.02 CR2006** – determine, through investigation using technology, and describe the roles of the parameters a, k, d,and c in functions of the form $y = af(k(x - d)) + c$ in terms of transformations on the graph of $f(x) = a^x (a > 0, a \neq 1)$ (i.e., translations; reflections in the axes; vertical and horizontal stretches and compressions) [Sample problem: Investigate the graph f(x) =3x - d- 5 for various values of d, using technology, and describe the effects of changing d in terms of a transformation.];
- ☐ **EF2.04 CR2006** – determine, through investigation using technology, that the equation of a given exponential function can be expressed using different bases [e.g.,$f(x) = 9^x$ can be expressed as $f(x) = 3^{2x}$], and explain the connections between the equivalent forms in a variety of ways (e.g., comparing graphs; using transformations; using the exponent laws);
- ☐ **EF2.05 CR2006** – represent an exponential function with an equation, given its graph or its properties (Sample problem: Write two equations to represent the same exponential function with a y-intercept of 5 and an asymptoteat y = 3. Investigate whether other exponential functions have the same properties. Use transformations to explain your observations.).

Solving Problems Involving Exponential Functions

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- ☐ **EF3.01** **CR2006** – collect data that can be modelled as an exponential function, through investigation with and without technology, from primary sources, using a variety of tools (e.g., concrete materials such as number cubes, coins; measurement tools such as electronic probes), or from secondary sources (e.g., websites such as Statistics Canada, E-STAT), and graph the data (Sample problem: Collect data and graph the cooling curve representing the relationship between temperature and time for hot water cooling in a porcelain mug. Predict the shape of the cooling curve when hot water cools in an insulated mug. Test your prediction.);

- ☐ **EF3.02** **CR2006** – identify exponential functions, including those that arise from real-world applications involving growth and decay (e.g., radioactive decay, population growth, cooling rates, pressure in a leaking tire), given various representations (i.e., tables of values, graphs, equations), and explain any restrictions that the context places on the domain and range (e.g., ambient temperature limits the range for a cooling curve) (Sample problem: Using data from Statistics Canada, investigate to determine if there was a period of time over which the increase in Canada?s national debt could be modelled using an exponential function.);

Gr.11 Functions---Discrete Functions MCR 3U

Representing Sequences

- ☐ **DF1.05** **CR2006** – determine, through investigation, recursive patterns in the Fibonacci sequence, in related sequences, and in Pascal's triangle, and represent the patterns in a variety of ways (e.g., tables of values, algebraic notation);
- ☐ **DF1.06** **CR2006** – determine, through investigation, and describe the relationship between Pascal?s triangle and the expansion of binomials, and apply the relationship to expand binomials raised to whole-number exponents [e.g., $(1 + x)^4$, $(2x - 1)^5$, $(2x - y)^6$, $(x^2 + 1)^5$].

Investigating Arithmetic and Geometric Sequences and Series

- ☐ **DF2.02** **CR2006** – determine the formula for the general term of an arithmetic sequence [i.e., $t_n = a + (n -1)d$] or geometric sequence (i.e., $t_n = ar^{n-1}$), through investigation using a variety of tools (e.g., linking cubes, algebra tiles, diagrams, calculators) and strategies (e.g., patterning; connecting the steps in a numerical example to the steps in the algebraic development), and apply the formula to calculate any term in a sequence;
- ☐ **DF2.03** **CR2006** – determine the formula for the sum of an arithmetic or geometric series, through investigation using a variety of tools (e.g., linking cubes, algebra tiles, diagrams, calculators) and strategies (e.g., patterning; connecting the steps in a numerical example to the steps in the algebraic development), and apply the formula to calculate the sum of a given number of consecutive terms (Sample problem: Given the array built with grey and white connecting cubes, investigate how different ways of determining the total number of grey cubes can be used to evaluate the sum of the arithmetic series 1 + 2 + 3 + 4 + 5. Extend the series, use patterning to make generalizations for finding the sum, and test the generalizations for other arithmetic series.);(omitted graphic on page 38)

Solving Problems Involving Financial Applications

- ☐ **DF3.01** **CR2006** – make and describe connections between simple interest, arithmetic sequences, and linear growth, through investigation with technology (e.g., use a spreadsheet or graphing calculator to make simple interest calculations, determine first differences in the amounts over time, and graph amount versus time) [Sample problem: Describe an investment that could be represented by the function f (x) = 500(1.05x).];
- ☐ **DF3.02** **CR2006** – make and describe connections between compound interest, geometric sequences, and exponential growth, through investigation with technology (e.g., use a spreadsheet to make compound interest calculations, determine finite differences in the amounts over time, and graph amount versus time) [Sample problem: Describe an investment that could be represented by the function f (x) = $500(1.05)^x$.];
- ☐ **DF3.03** **CR2006** – solve problems, using a scientific calculator, that involve the calculation of the amount, A (also referred to as future value, FV), the principal, P (also referred to as present value, PV), or the interest rate per compounding period, i, using the compound interest formula in the form $A = P (1 + i)^n$ [or $FV = PV(1 + i)^n$] (Sample problem: Two investments are available, one at 6% compounded annually and the other at 6% compounded monthly. Investigate graphically the growth of each investment, and determine the interest earned from depositing $1000 in each investment for 10 years.);

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within: **Mathematics**

- ☐ **DF3.04** **CR2006** – determine, through investigation using technology (e.g., scientific calculator; the TVM solver in a graphing calculator; online tools), and describe strategies (e.g., guessing and checking; using the power of a power rule for exponents; using graphs) for calculating the number of compounding periods, n, using the compound interest formula in the form $A = P(1 + i)^n$ [or $FV = PV(1 + i)^n$], and solve related problems;
- ☐ **DF3.05** **CR2006** – explain the meaning of the term annuity, and determine the relationships between ordinary annuities, geometric series, and exponential growth, through investigation with technology in situations where the compounding period and the payment period are the same (e.g., use a spreadsheet to determine and graph the future value of an ordinary annuity for varying numbers of compounding periods; investigate how the contributions of each payment to the future value of an ordinary annuity are related to the terms of a geometric series);
- ☐ **DF3.06** **CR2006** – determine, through investigation using technology (e.g., the TVM Solver in a graphing calculator; online tools), the effects of changing the conditions (i.e., the payments, the frequency of the payments, the interest rate, the compounding period) of ordinary annuities in situations where the compounding period and the payment period are the same (e.g., long-term savings plans, loans) (Sample problem: Compare the amounts at age 65 that would result from making an annual deposit of $1000 starting at age 20, or from making an annual deposit of $3000 starting at age 50, to an RRSP that earns 6% interest per annum, compounded annually. What is the total of the deposits in each situation?);

Gr.11 Functions---Trigonometric Functions MCR 3U

Determining and Applying Trigonometric Ratios

- ☐ **TF1.02** **CR2006** – determine the values of the sine, cosine, and tangent of angles from 0° to 360°, through investigation using a variety of tools (e.g., dynamic geometry software, graphing tools) and strategies (e.g., applying the unit circle; examining angles related to special angles);

Connecting Graphs and Equations of Sinusoidal Functions

- ☐ **TF2.05** **CR2006** – determine, through investigation using technology, and describe the roles of the parameters a, k, d,and c in functions of the form $y = af(k(x - d)) + c$ in terms of transformations on the graphs of $f(x) = \sin x$ and $f(x) = \cos x$ with angles expressed in degrees (i.e., translations; reflections in the axes; vertical and horizontal stretches and compressions) [Sample problem: Investigate the graph $f(x) = 2\sin(x - d) + 10$ for various values of d, using technology, and describe the effects of changing d in terms of a transformation.];

Solving Problems Involving Sinusoidal Functions

- ☐ **TF3.01** **CR2006** – collect data that can be modelled as a sinusoidal function (e.g., voltage in an AC circuit, sound waves), through investigation with and without technology, from primary sources, using a variety of tools (e.g., concrete materials; measurement tools such as motion sensors), or from secondary sources (e.g., websites such as Statistics Canada, E-STAT), and graph the data (Sample problem: Measure and record distance-time data for a swinging pendulum, using a motion sensor or other measurement tools, and graph the data.);
- ☐ **TF3.02** **CR2006** – identify sinusoidal functions, including those that arise from real-world applications involving periodic phenomena, given various representations (i.e., tables of values, graphs, equations), and explain any restrictions that the context places on the domain and range (Sample problem: Using data from Statistics Canada, investigate to determine if there was a period of time over which changes in the population of Canadians aged 20-24 could be modelled using a sinusoidal function.);
- ☐ **TF3.03** **CR2006** – determine, through investigation, how sinusoidal functions can be used to model periodic phenomena that do not involve angles [Sample problem: Investigate,using graphing technology in degree mode, and explain how the function $h(t) = 5\sin(30(t + 3))$ approximately models the relationship between the height and the time of day for a tide with an amplitude of 5 m, if high tide is at midnight.];

Gr.12 Mathematics for College Technology---Mathematics Process Specific Expectations MCT 4C

Problem Solving

- ☐ **MPS.01** **CR2007** • develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

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within: **Mathematics**

Reflecting

☐ **MPS.03** **CR2007** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **MPS.04** **CR2007** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.12 Mathematics for College Technology---A. EXPONENTIAL FUNCTIONS MCT 4C

1. Solving Exponential Equations Graphically

☐ **EF1.01** **CR2007** 1.1 determine, through investigation with technology, and describe the impact of changing the base and changing the sign of the exponent on the graph of an exponential function

☐ **EF1.03** **CR2007** 1.3 determine, through investigation using graphing technology, the point of intersection of the graphs of two exponential functions (e.g., $y = 4^{-x}$ and $y = 8^{x+3}$), recognize the x-coordinate of this point to be the solution to the corresponding exponential equation (e.g., $4^{-x} = 8^{x+3}$), and solve exponential equations graphically (e.g., solve $2^{x+2} = 2^x + 12$ by using the intersection of the graphs of $y = 2^{x+2}$ and $y = 2^x + 12$) Sample problem: Solve $0.5^x = 3^{x+3}$ graphically.

2. Solving Exponential Equations Algebraically

☐ **EF2.02** **CR2007** 2.2 solve exponential equations in one variable by determining a common base (e.g., $2^x = 32$, $4^{5x-1} = 2^{2(x+11)}$, $3^{5x+8} = 27^x$) Sample problem: Solve $3^{5x+8} = 27^x$ by determining a common base, verify by substitution, and investigate connections to the intersection of $y = 3^{5x+8}$ and $y = 27^x$ using graphing technology.

Gr.12 Mathematics for College Technology---B. POLYNOMIAL FUNCTIONS MCT 4C

1. Investigating Graphs of Polynomial Functions

☐ **PF1.02** **CR2007** 1.2 compare, through investigation using graphing technology, the graphical and algebraic representations of polynomial (i.e., linear, quadratic, cubic, quartic) functions (e.g., investigate the effect of the degree of a polynomial function on the shape of its graph and the maximum number of x-intercepts; investigate the effect of varying the sign of the leading coefficient on the end behaviour of the function for very large positive or negative x-values) Sample problem: Investigate the maximum number of x-intercepts for linear, quadratic, cubic, and quartic functions using graphing technology.

2. Connecting Graphs and Equations of Polynomial Functions

☐ **PF2.02** **CR2007** 2.2 make connections, through investigation using graphing technology (e.g., dynamic geometry software), between a polynomial function given in factored form [e.g., $f(x) = x(x - 1)(x + 1)$] and the x-intercepts of its graph, and sketch the graph of a polynomial function given in factored form using its key features (e.g., by determining intercepts and end behaviour; by locating positive and negative regions using test values between and on either side of the x-intercepts) Sample problem: Sketch the graphs of $f(x) = -(x - 1)(x + 2)(x - 4)$ and $g(x) = -(x - 1)(x + 2)(x + 2)$ and compare their shapes and the number of x-intercepts.

☐ **PF2.03** **CR2007** 2.3 determine, through investigation using technology (e.g., graphing calculator, computer algebra systems), and describe the connection between the real roots of a polynomial equation and the x-intercepts of the graph of the corresponding polynomial function [e.g., the real roots of the equation $x^4 - 13x^2 + 36 = 0$ are the x-intercepts of the graph of $f(x) = x^4 - 13x^2 + 36$] Sample problem: Describe the relationship between the x-intercepts of the graphs of linear and quadratic functions and the real roots of the corresponding equations. Investigate, using technology, whether this relationship exists for polynomial functions of higher degree.

Gr.12 Mathematics for College Technology---C. TRIGONOMETRIC FUNCTIONS MCT 4C

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containing the term(s): **investigate OR investigation**
within: **Gr.7, Gr.8, Gr.9, Gr.10, Gr.11, Gr.12**
within: **Mathematics**

1. Applying Trigonometric Ratios

☐ **TF1.02** **CR2007** 1.2 determine the values of the sine, cosine, and tangent of angles from 0° to 360°, through investigation using a variety of tools (e.g., dynamic geometry software, graphing tools) and strategies (e.g., applying the unit circle; examining angles related to the special angles)

2. Connecting Graphs and Equations of Sinusoidal Functions

☐ **TF2.03** **CR2007** 2.3 determine, through investigation using technology, the roles of the parameters d and c in functions of the form $y = \sin(x - d) + c$ and $y = \cos(x - d) + c$, and describe these roles in terms of transformations on the graphs of $f(x) = \sin x$ and $f(x) = \cos x$ with angles expressed in degrees (i.e., vertical and horizontal translations) Sample problem: Investigate the graph $f(x) = 2\sin(x - d) + 10$ for various values of d, using technology, and describe the effects of changing d in terms of a transformation.

☐ **TF2.04** **CR2007** 2.4 determine, through investigation using technology, the roles of the parameters a and k in functions of the form $y = a \sin kx$ and $y = a \cos kx$, and describe these roles in terms of transformations on the graphs of $f(x) = \sin x$ and $f(x) = \cos x$ with angles expressed in degrees (i.e., reflections in the axes; vertical and horizontal stretches and compressions to and from the x- and y-axes) Sample problem: Investigate the graph $f(x) = 2\sin kx$ for various values of k, using technology, and describe the effects of changing k in terms of transformations.

3. Solving Problems Involving Sinusoidal Functions

☐ **TF3.01** **CR2007** 3.1 collect data that can be modelled as a sinusoidal function (e.g., voltage in an AC circuit, pressure in sound waves, the height of a tack on a bicycle wheel that is rotating at a fixed speed), through investigation with and without technology, from primary sources, using a variety of tools (e.g., concrete materials, measurement tools such as motion sensors), or from secondary sources (e.g., websites such as Statistics Canada, E-STAT), and graph the data Sample problem: Measure and record distance-time data for a swinging pendulum, using a motion sensor or other measurement tools, and graph the data. Describe how the graph would change if you moved the pendulum further away from the motion sensor. What would you do to generate a graph with a smaller amplitude?

Gr.12 Mathematics for College Technology---D. APPLICATIONS OF GEOMETRY MCT 4C

1. Modelling With Vectors

☐ **AG1.05** **CR2007** 1.5 determine, through investigation using a variety of tools (e.g., graph paper, technology) and strategies (i.e., head-to-tail method; parallelogram method; resolving vectors into their vertical and horizontal components), the sum (i.e., resultant) or difference of two vectors

3. Solving Problems Involving Circle Properties

☐ **AG3.03** **CR2007** 3.3 determine, through investigation using a variety of tools (e.g., dynamic geometry software), properties of the circle associated with chords, central angles, inscribed angles, and tangents (e.g., equal chords or equal arcs subtend equal central angles and equal inscribed angles; a radius is perpendicular to a tangent at the point of tangency defined by the radius, and to a chord that the radius bisects) Sample problem: Investigate, using dynamic geometry software, the relationship between the lengths of two tangents drawn to a circle from a point outside the circle.

Gr.12 Calculus and Vectors---Mathematics Process Specific Expectations MCV 4U

Problem Solving

☐ **MPS.01** **CR2007** • develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **MPS.03** **CR2007** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

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within: **Mathematics**

☐ **MPS.04** **CR2007** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.12 Calculus and Vectors---A. RATE OF CHANGE MCV 4U

1. Investigating Instantaneous Rate of Change at a Point

☐ **RC1.04** **CR2007** 1.4 recognize, through investigation with or without technology, graphical and numerical examples of limits, and explain the reasoning involved (e.g., the value of a function approaching an asymptote, the value of the ratio of successive terms in the Fibonacci sequence) Sample problem: Use appropriate technology to investigate the limiting value of the terms in the sequence $(1 +1/1)^1$, $(1 +1/2)^2$, $(1 +1/3)^3$, $(1 +1/4)^4$, ..., and the limiting value of the series $4 \times 1 – 4 \times 1/3 + 4 \times 1/5 –4 \times 1/7 + 4 \times 1/9 – ....$

☐ **RC1.06** **CR2007** 1.6 compare, through investigation, the calculation of instantaneous rates of change at a point (a, f(a)) for polynomial functions [e.g., $f(x) = x^2$, $f(x) = x^3$,], with and without $[f(a + h) – f(a)]/h$ simplifying the expression before substituting values of that approach zero [e.g., for $f(x) = x^2$ at x = 3, by determining $[f(3 + 1) – f(3)]/1 = 7$, $[f(3 + 0.1) – f(3)]/ 0.01 = 6.1$, $[f(3 + 0.01) – f(3)]/0.01 = 6.01$, and $[f(3 + 0.001) – f(3)]/0.001 = 6.001$, and by first simplifying $[f(3 + h) – f(3)]/h$ as $[(3 + h)^2– 3^2]/h = 6 + h$ and then substituting the same values of h to give the same results]

2. Investigating the Concept of the Derivative Function

☐ **RC2.02** **CR2007** 2.2 generate, through investigation using technology, a table of values showing the instantaneous rate of change of a polynomial function, f(x), for various values of x (e.g., construct a tangent to the function, measure its slope, and create a slider or animation to move the point of tangency), graph the ordered pairs, recognize that the graph represents a function called the derivative, f'(x) or dy/dx, and make connections between the graphs of f(x) and f'(x) or y and dy/dx [e.g., when f(x) is linear, f'(x) is constant; when f(x) is quadratic, f'(x) is linear; when f(x) is cubic, f'(x) is quadratic] Sample problem: Investigate, using patterning strategies and graphing technology, relationships between the equation of a polynomial function of degree no higher than 3 and the equation of its derivative.

☐ **RC2.04** **CR2007** 2.4 determine, through investigation using technology, the graph of the derivative f'(x)or dy/dx of a given sinusoidal function [i.e., f(x) = sin x, f(x) = cos x] (e.g., by generating a table of values showing the instantaneous rate of change of the function for various values of x and graphing the ordered pairs; by using dynamic geometry software to verify graphically that when f(x) = sin x, f'(x) = cos x, and when f(x) = cos x, f'(x) =– sin x; by using a motion sensor to compare the displacement and velocity of a pendulum)

☐ **RC2.05** **CR2007** 2.5 determine, through investigation using technology, the graph of the derivative f'(x)or dy/dx of a given exponential function [i.e., $f(x) = a^x$ $(a > 0, a \neq 1)$] [e.g., by generating a table of values showing the instantaneous rate of change of the function for various values of x and graphing the ordered pairs; by using dynamic geometry software to verify that when $f(x) = a^x$, $f'(x) = kf(x)$], and make connections between the graphs of f(x) and f'(x) or y and dy/dx [e.g., f(x) and f'(x) are both exponential; the ratio f'(x)/f(x) is constant, or $f'(x) = kf(x)$; f'(x) is a vertical stretch from the x-axis of f(x)] Sample problem: Graph, with technology, $f(x) = a^x$ $(a > 0, a \neq 1)$ and f'(x) on the same set of axes for various values of a (e.g., 1.7, 2.0, 2.3, 3.0, 3.5). For each value of a, investigate the ratio f'(x)/f(x) for various values of x, and explain how you can use this ratio to determine the slopes of tangents to f(x).

☐ **RC2.06** **CR2007** 2.6 determine, through investigation using technology, the exponential function $f(x) = a^x (a > 0, a \neq 1)$ for which $f'(x) = f(x)$ (e.g., by using graphing technology to create a slider that varies the value of a in order to determine the exponential function whose graph is the same as the graph of its derivative), identify the number e to be the value of a for which $f'(x) = f(x)$ [i.e., given $f(x) = e^x$, $f(x) = e^x$], and recognize that for the exponential function $f(x) = e^x$ the slope of the tangent at any point on the function is equal to the value of the function at that point Sample problem: Use graphing technology to determine an approximate value of e by graphing $f(x) = a^x$ $(a > 0, a \neq 1)$ for various values of a, comparing the slope of the tangent at a point with the value of the function at that point, and identifying the value of a for which they are equal.

Gr.12 Calculus and Vectors---B. DERIVATIVES AND THEIR APPLICATIONS MCV 4U

1. Connecting Graphs and Equations of Functions and Their Derivatives

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within: **Mathematics**

- ☐ **DA1.01** **CR2007** 1.1 sketch the graph of a derivative function, given the graph of a function that is continuous over an interval, and recognize points of inflection of the given function (i.e., points at which the concavity changes) Sample problem: Investigate the effect on the graph of the derivative of applying vertical and horizontal translations to the graph of a given function.
- ☐ **DA1.03** **CR2007** 1.3 determine algebraically the equation of the second derivative f''(x) of a polynomial or simple rational function f(x), and make connections, through investigation using technology, between the key features of the graph of the function (e.g., increasing/decreasing intervals, local maxima and minima, points of inflection, intervals of concavity) and corresponding features of the graphs of its first and second derivatives (e.g., for an increasing interval of the function, the first derivative is positive; for a point of inflection of the function, the slopes of tangents change their behaviour from increasing to decreasing or from decreasing to increasing, the first derivative has a maximum or minimum, and the second derivative is zero)
  Sample problem: Investigate, using graphing technology, connections between key properties, such as increasing/decreasing intervals, local maxima and minima, points of inflection, and intervals of concavity, of the functions $f(x) = 4x + 1$, $f(x) = x^2 + 3x - 10$, $f(x) = x^3 + 2x^2 - 3x$, and $f(x) = x^4 + 4x^3 - 3x^2 - 18x$ and the graphs of their first and second derivatives.

Gr.12 Calculus and Vectors---C. GEOMETRY AND ALGEBRA OF VECTORS MCV 4U

2. Operating With Vectors

- ☐ **GA2.02** **CR2007** 2.2 determine, through investigation with and without technology, some properties (e.g., commutative, associative, and distributive properties) of the operations of addition, subtraction, and scalar multiplication of vectors
- ☐ **GA2.05** **CR2007** 2.5 determine, through investigation, properties of the dot product (e.g., investigate whether it is commutative, distributive, or associative; investigate the dot product of a vector with itself and the dot product of orthogonal vectors) Sample problem: Investigate geometrically and algebraically the relationship between the dot product of the vectors (1, 0, 1) and (0, 1, – 1) and the dot product of scalar multiples of these vectors. Does this relationship apply to any two vectors? Find a vector that is orthogonal to both the given vectors.
- ☐ **GA2.07** **CR2007** 2.7 determine, through investigation, properties of the cross product (e.g., investigate whether it is commutative, distributive, or associative; investigate the cross product of collinear vectors) Sample problem: Investigate algebraically the relationship between the cross product of the vectors vector a = (1, 0, 1) and vector b = (0, 1, – 1) and the cross product of scalar multiples of vector a and vector b. Does this relationship apply to any two vectors?
- ☐ **GA2.08** **CR2007** 2.8 solve problems involving dot product and cross product (e.g., determining projections, the area of a parallelogram, the volume of a parallelepiped), including problems arising from real-world applications (e.g., determining work, torque, ground speed, velocity, force) Sample problem: Investigate the dot products vector a •(vector a x vector b) and vector b •(vector a x vector b) for any two vectors vector a and vector b in three-space. What property of the cross product vector a x vector b does this verify?

3. Describing Lines and Planes Using Linear Equations

- ☐ **GA3.02** **CR2007** 3.2 determine, through investigation with technology (i.e., 3-D graphing software) and without technology, that the solution points (x, y, z) in three-space of a single linear equation in three variables form a plane and that the solution points (x, y, z) in three-space of a system of two linear equations in three variables form the line of intersection of two planes, if the planes are not coincident or parallel Sample problem: Use spatial reasoning to compare the shapes of the solutions in three-space with the shapes of the solutions in two-space for each of the linear equations x = 0, y = 0, and y = x. For each of the equations z = 5, y – z = 3, and x + z = 1, describe the shape of the solution points (x, y, z) in three-space. Verify the shapes of the solutions in three-space using technology.
- ☐ **GA3.03** **CR2007** 3.3 determine, through investigation using a variety of tools and strategies (e.g., modelling with cardboard sheets and drinking straws; sketching on isometric graph paper), different geometric configurations of combinations of up to three lines and/or planes in three-space (e.g., two skew lines, three parallel planes, two intersecting planes, an intersecting line and plane); organize the configurations based on whether they intersect and, if so, how they intersect (i.e., in a point, in a line, in a plane)

4. Describing Lines and Planes Using Scalar, Vector, and Parametric Equations

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☐ **GA4.03** **CR2007**
4.3 recognize a normal to a plane geometrically (i.e., as a vector perpendicular to the plane) and algebraically [e.g., one normal to the plane 3x + 5y – 2z = 6 is (3, 5, –2)], and determine, through investigation, some geometric properties of the plane (e.g., the direction of any normal to a plane is constant; all scalar multiples of a normal to a plane are also normals to that plane; three non-collinear points determine a plane; the resultant, or sum, of any two vectors in a plane also lies in the plane) Sample problem: How does the relationship vector a •(vector b x vector c) = 0 help you determine whether three non-parallel planes intersect in a point, if vector a, vector b, and vector c represent normals to the three planes?

Gr.12 Mathematics of Data Management---Mathematics Process Specific Expectations MDM 4U

Problem Solving

☐ **MPS.01** **CR2007**
• develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **MPS.03** **CR2007**
• demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **MPS.04** **CR2007**
• select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.12 Mathematics of Data Management---A. COUNTING AND PROBABILITY MDM 4U

1. Solving Probability Problems Involving Discrete Sample Spaces

☐ **CP1.04** **CR2007**
1.4 determine, through investigation using class-generated data and technology-based simulation models (e.g., using a random-number generator on a spreadsheet or on a graphing calculator; using dynamic statistical software to simulate repeated trials in an experiment), the tendency of experimental probability to approach theoretical probability as the number of trials in an experiment increases (e.g., "If I simulate tossing two coins 1000 times using technology, the experimental probability that I calculate for getting two tails on the two tosses is likely to be closer to the theoretical probability of 1/4 than if I simulate tossing the coins only 10 times")
Sample problem: Calculate the theoretical probability of rolling a 2 on a single roll of a number cube. Simulate rolling a number cube, and use the simulation results to calculate the experimental probabilities of rolling a 2 over 10, 20, 30, ..., 200 trials. Graph the experimental probabilities versus the number of trials, and describe any trend.

2. Solving Problems Using Counting Principles

☐ **CP2.04** **CR2007**
2.4 make connections, through investigation, between combinations (i.e., n choose r) and Pascal's triangle [e.g., between C(2, r) and row 3 of Pascal's triangle, between C(n, 2) and diagonal 3 of Pascal's triangle] Sample problem: A school is 5 blocks west and 3 blocks south of a student's home. Determine, in a variety of ways (e.g., by drawing the routes, by using Pascal's triangle, by using combinations), how many different routes the student can take from home to the school by going west or south at each corner.

Gr.12 Mathematics of Data Management---B. PROBABILITY DISTRIBUTIONS MDM 4U

2. Understanding Probability Distributions for Continuous Random Variables

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within: **Mathematics**

☐ **PD2.04** **CR2007** 2.4 represent, using intervals, a sample of values of a continuous random variable numerically using a frequency table and graphically using a frequency histogram and a frequency polygon, recognize that the frequency polygon approximates the frequency distribution, and determine, through investigation using technology (e.g., dynamic statistical software, graphing calculator), and compare the effectiveness of the frequency polygon as an approximation of the frequency distribution for different sizes of the intervals

☐ **PD2.07** **CR2007** 2.7 make connections, through investigation using dynamic statistical software, between the normal distribution and the binomial and hypergeometric distributions for increasing numbers of trials of the discrete distributions (e.g., recognizing that the shape of the hypergeometric distribution of the number of males on a 4-person committee selected from a group of people more closely resembles the shape of a normal distribution as the size of the group from which the committee was drawn increases) Sample problem: Explain how the total area of a probability histogram for a binomial distribution allows you to predict the area under a normal probability distribution curve.

Gr.12 Mathematics of Data Management---C. ORGANIZATION OF DATA FOR ANALYSIS MDM 4U

1. Understanding Data Concepts

☐ **OD1.02** **CR2007** 1.2 recognize and explain reasons why variability is inherent in data (e.g., arising from limited accuracy in measurement or from variations in the conditions of an experiment; arising from differences in samples in a survey), and distinguish between situations that involve one variable and situations that involve more than one variable Sample problem: Use the Census at School database to investigate variability in the median and mean of, or a proportion estimated from, equal-sized random samples of data on a topic such as the percentage of students who do not smoke or who walk to school, or the average height of people of a particular age. Compare the median and mean of, or a proportion estimated from, samples of increasing size with the median and mean of the population or the population proportion.

Gr.12 Mathematics of Data Management---D. STATISTICAL ANALYSIS MDM 4U

1. Analysing One-Variable Data

☐ **SA1.04** **CR2007** 1.4 interpret, for a normally distributed population, the meaning of a statistic qualified by a statement describing the margin of error and the confidence level (e.g., the meaning of a statistic that is accurate to within 3 percentage points, 19 times out of 20), and make connections, through investigation using technology (e.g., dynamic statistical software), between the sample size, the margin of error, and the confidence level (e.g., larger sample sizes create higher confidence levels for a given margin of error) Sample problem: Use census data from Statistics Canada to investigate, using dynamic statistical software, the minimum sample size such that the proportion of the sample opting for a particular consumer or voting choice is within 3 percentage points of the proportion of the population, 95% of the time (i.e., 19 times out of 20).

Gr.12 Mathematics of Data Management---E. CULMINATING DATA MANAGEMENT INVESTIGATION MDM 4U

Overall Expectations

☐ **CDV.01** **CR2007** 1. design and carry out a culminating investigation* that requires the integration and application of the knowledge and skills related to the expectations of this course;

☐ **CDV.02** **CR2007** 2. communicate the findings of a culminating investigation and provide constructive critiques of the investigations of others.

1. Designing and Carrying Out a Culminating Investigation

☐ **CD1.05** **CR2007** 1.5 draw conclusions from the analysis of the data (e.g., determine whether the analysis solves the problem), evaluate the strength of the evidence (e.g., by considering factors such as sample size or bias, or the number of times a game is played), specify any limitations of the conclusions, and suggest follow-up problems or investigations

2. Presenting and Critiquing the Culminating Investigation

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within: **Mathematics**

☐	**CD2.01** **CR2007**	2.1 compile a clear, well-organized, and detailed report of the investigation
☐	**CD2.02** **CR2007**	2.2 present a summary of the culminating investigation to an audience of their peers within a specified length of time, with technology (e.g. presentation software) or without technology
☐	**CD2.03** **CR2007**	2.3 answer questions about the culminating investigation and respond to critiques (e.g., by elaborating on the procedures; by justifying mathematical reasoning)
☐	**CD2.04** **CR2007**	2.4 critique the mathematical work of others in a constructive manner *This culminating investigation allows students to demonstrate their knowledge and skills from this course by addressing a single problem on probability and statistics or by addressing two smaller problems, one on probability and the other on statistics.

Gr.11 Mathematics for Work and Everyday Life---Mathematics Process Specific Expectations MEL 3E

Problem Solving

☐	**MPS.01** **CR2006**	• develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐	**MPS.03** **CR2006**	• demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐	**MPS.04** **CR2006**	• select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.11 Mathematics for Work and Everyday Life---Earning and Purchasing MEL 3E

Purchasing

☐	**EP3.08** **CR2006**	– compare the unit prices of related items to help determine the best buy (Sample problem: Investigate whether or not purchasing larger quantities always results in a lower unit price.);
☐	**EP3.10** **CR2006**	– make and justify a decision regarding the purchase of an item, using various criteria (e.g., extra costs, such as shipping costs and transaction fees; quality and quantity of the item; shelf life of the item; method of purchase, such as online versus local) under various circumstances (e.g., not having access to a vehicle; living in a remote community; having limited storage space) (Sample problem: I have to take 100 mL of a liquid vitamin supplement every morning. I can buy a 100 mL size for $6.50 or a 500 mL size for $25.00. If the supplement keeps in the refrigerator for only 72 h, investigate which size is the better buy. Explain your reasoning.).

Gr.11 Mathematics for Work and Everyday Life---Saving, Investing, and Borrowing MEL 3E

Saving and Investing

☐	**SI2.01** **CR2006**	– determine, through investigation using technology (e.g., calculator, spreadsheet), the effect on simple interest of changes in the principal, interest rate, or time, and solve problems involving applications of simple interest;
☐	**SI2.02** **CR2006**	– determine, through investigation using technology, the compound interest for a given investment, using repeated calculations of simple interest for no more than 6 compounding periods (Sample problem: Someone deposits $5000 at 4% interest per annum, compounded semi-annually. How much interest accumulates in 3 years?);

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within: **Mathematics**

☐ **SI2.04** **CR2006** – determine, through investigation using technology (e.g., a TVM Solver in a graphing calculator or on a website), the effect on the future value of a compound interest investment of changing the total length of time, the interest rate, or the compounding period (Sample problem: Compare the results at age 40 of making a deposit of $1000 at age 20 or a deposit of $2000 at age 30, if both investments pay 6% interest per annum, compounded monthly.);

Gr.11 Mathematics for Work and Everyday Life---Transportation and Travel MEL 3E

Owning and Operating a Vehicle

☐ **TT1.03** **CR2006** – gather and interpret information about the procedures and costs involved in insuring a vehicle (e.g., car, motorcycle, snowmobile) and the factors affecting insurance rates (e.g., gender, age, driving record, model of vehicle, use of vehicle), and compare the insurance costs for different categories of drivers and for different vehicles (Sample problem: Use automobile insurance websites to investigate the degree to which the type of car and the age and gender of the driver affect insurance rates.);

Comparing Modes of Transportation

☐ **TT3.02** **CR2006** – gather, interpret, and compare information about the costs (e.g., insurance; extra charges based on distance travelled) and conditions (e.g., one-way or return; drop-off time and location; age of the driver; required type of driver's licence) involved in renting a car, truck, or trailer, and use the information to justify a choice of rental vehicle (Sample problem: You want to rent a trailer or a truck to help you move to a new apartment. Investigate the costs and describe the conditions that favour each option.);

☐ **TT3.04** **CR2006** – solve problems involving the comparison of information concerning transportation by airplane, train, bus, and automobile in terms of various factors (e.g., cost, time, convenience) (Sample problem: Investigate the cost of shipping a computer from Thunder Bay to Windsor by airplane, train, or bus. Describe the conditions that favour each alternative.).

Gr.12 Mathematics for Work and Everyday Life---Mathematics Process Specific Expectations MEL 4E

Problem Solving

☐ **MPS.01** **CR2007** • develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **MPS.03** **CR2007** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **MPS.04** **CR2007** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.12 Mathematics for Work and Everyday Life---A. REASONING WITH DATA MEL 4E

2. Investigating Probability

☐ **RD2.04** **CR2007** 2.4 compare, through investigation, the theoretical probability of an event with the experimental probability, and describe how uncertainty explains why they might differ (e.g., I know that the theoretical probability of getting tails is 0.50, but that does not mean that I will always obtain 3 tails when I toss the coin 6 times"; "If a lottery has a 1 in 9 chance of winning, am I certain to win if I buy 9 tickets?")

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within: **Gr.7, Gr.8, Gr.9, Gr.10, Gr.11, Gr.12**
within: **Mathematics**

☐ **RD2.05** **CR2007**
2.5 determine, through investigation using class-generated data and technology-based simulation models (e.g., using a random-number generator on a spreadsheet or on a graphing calculator), the tendency of experimental probability to approach theoretical probability as the number of trials in an experiment increases (e.g., "If I simulate tossing a coin 1000 times using technology, the experimental probability that I calculate for getting tails in any one toss is likely to be closer to the theoretical probability than if I simulate tossing the coin only 10 times")
Sample problem: Calculate the theoretical probability of rolling a 2 on a number cube. Simulate rolling a number cube, and use the simulation to calculate the experimental probability of rolling a 2 after 10, 20, 30, ..., 200 trials. Graph the experimental probability versus the number of trials, and describe any trend.

☐ **RD2.06** **CR2007**
2.6 interpret information involving the use of probability and statistics in the media, and describe how probability and statistics can help in making informed decisions in a variety of situations (e.g., weighing the risk of injury when considering different occupations; using a weather forecast to plan outdoor activities; using sales data to stock a clothing store with appropriate styles and sizes) Sample problem: A recent study on youth gambling suggests that approximately 30% of adolescents gamble on a weekly basis. Investigate and describe the assumptions that people make about the probability of winning when they gamble. Describe other factors that encourage gambling and problems experienced by people with a gambling addiction.

Gr.12 Mathematics for Work and Everyday Life---B. PERSONAL FINANCE MEL 4E

1. Renting or Owning Accommodation

☐ **PS1.02** **CR2007**
1.2 gather and compare, through investigation, information about the costs and the advantages and disadvantages of different types of rental accommodation in the local community (e.g., renting a room in someone's house; renting a hotel room; renting or leasing an apartment)

☐ **PS1.03** **CR2007**
1.3 gather and compare, through investigation, information about purchase prices of different types of owned accommodation in the local community (e.g., trailer, condominium, townhouse, detached home)

Gr.12 Mathematics for Work and Everyday Life---C. APPLICATIONS OF MEASUREMENT MEL 4E

2. Applying Measurement and Design

☐ **AM2.08** **CR2007**
2.8 investigate, plan, design, and prepare a budget for a household improvement (e.g., landscaping a property; renovating a room), using appropriate technologies (e.g., design or decorating websites, design or drawing software, spreadsheet) Sample problem: Plan, design, and prepare a budget for the renovation of a 12-ft by 12-ft bedroom for under $2000. The renovations could include repainting the walls, replacing the carpet with hardwood flooring, and refurnishing the room.

Gr.9 Foundations of Mathematics---Mathematical Process Specific Expectations MFM 1P

Problem Solving

☐ **MPS.01** **SQC2005**
• develop, select, apply, and compare a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **MPS.03** **SQC2005**
• demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **MPS.04** **SQC2005**
• select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

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within: **Mathematics**

Gr.9 Foundations of Mathematics---Linear Relations MFM 1P

Overall Expectations

☐ **LRV.01** • apply data-management techniques to investigate relationships between two variables;
SQC2005

Using Data Management to Investigate Relationships

☐ **LR1.03** – carry out an investigation or experiment involving relationships between two variables, including the collection and organization of data, using appropriate methods, equipment, and/or technology (e.g., surveying; using measuring tools, scientific probes, the Internet) and techniques (e.g., making tables, drawing graphs) (Sample problem: Perform an experiment to measure and record the temperature of ice water in a plastic cup and ice water in a thermal mug over a 30 min period, for the purpose of comparison. What factors might affect the outcome of this experiment? How could you change the experiment to account for them?);
SQC2005

☐ **LR1.04** – describe trends and relationships observed in data, make inferences from data, compare the inferences with hypotheses about the data, and explain any differences between the inferences and the hypotheses (e.g., describe the trend observed in the data. Does a relationship seem to exist? Of what sort? Is the outcome consistent with your hypothesis? Identify and explain any outlying pieces of data. Suggest a formula that relates the variables. How might you vary this experiment to examine other relationships?) (Sample problem: Hypothesize the effect of the length of a pendulum on the time required for the pendulum to make five full swings. Use data to make an inference. Compare the inference with the hypothesis. Are there other relationships you might investigate involving pendulums?).
SQC2005

Determining Characteristics of Linear Relations

☐ **LR2.03** – identify, through investigation, some properties of linear relations (i.e., numerically, the first difference is a constant, which represents a constant rate of change; graphically, a straight line represents the relation), and apply these properties to determine whether a relation is linear or non-linear.
SQC2005

Investigating Constant Rate of Change

☐ **LR3.01** – determine, through investigation, that the rate of change of a linear relation can be found by choosing any two points on the line that represents the relation, finding the vertical change between the points (i.e., the rise) and the horizontal change between the points (i.e., the run), and writing the ratio rise/run (i.e., rate of change =rise/run);
SQC2005

☐ **LR3.02** – determine, through investigation, connections among the representations of a constant rate of change of a linear relation (e.g., the cost of producing a book of photographs is $50, plus $5 per book, so an equation is C = 50 + 5p; a table of values provides the first difference of 5; the rate of change has a value of 5; and 5 is the coefficient of the independent variable, p, in this equation);
SQC2005

Gr.9 Foundations of Mathematics---Measurement and Geometry MFM 1P

Overall Expectations

☐ **MGV.01** • determine, through investigation, the optimal values of various measurements of rectangles;
SQC2005

☐ **MGV.03** • determine, through investigation facilitated by dynamic geometry software, geometric properties and relationships involving two-dimensional shapes, and apply the results to solving problems.
SQC2005

Solving Problems Involving Perimeter, Area, and Volume

☐ **MG2.04** – develop, through investigation (e.g., using concrete materials), the formulas for the volume of a pyramid, a cone, and a sphere (e.g., use three-dimensional figures to show that the volume of a pyramid [or cone] is 1/3 the volume of a prism [or cylinder] with the same base and height, and therefore that Vpyramid = Vprism/3 or Vpyramid = ((area of base)(height))/3);
SQC2005

Investigating and Applying Geometric Relationships

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within: **Mathematics**

☐ **MG3.01** **SQC2005** – determine, through investigation using a variety of tools (e.g., dynamic geometry software, concrete materials), and describe the properties and relationships of the interior and exterior angles of triangles, quadrilaterals, and other polygons, and apply the results to problems involving the angles of polygons (Sample problem:With the assistance of dynamic geometry software, determine the relationship between the sum of the interior angles of a polygon and the number of sides. Use your conclusion to determine the sum of the interior angles of a 20-sided polygon.);

☐ **MG3.02** **SQC2005** – determine, through investigation using a variety of tools (e.g., dynamic geometry software, concrete materials), and describe the properties and relationships of the angles formed by parallel lines cut by a transversal, and apply the results to problems involving parallel lines (e.g., given a diagram of a rectangular gate with a supporting diagonal beam, and given the measure of one angle in the diagram, use the angle properties of triangles and parallel lines to determine the measures of the other angles in the diagram);

Gr.10 Foundations of Mathematics---Mathematical Process Specific Expectations MFM 2P

Problem Solving

☐ **MPS.01** **SQC2005** • develop, select, apply, and compare a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **MPS.03** **SQC2005** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **MPS.04** **SQC2005** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.10 Foundations of Mathematics---Measurement and Trigonometry MFM 2P

Overall Expectations

☐ **MTV.01** **SQC2005** • use their knowledge of ratio and proportion to investigate similar triangles and solve problems related to similarity;

Solving Problems Involving Similar Triangles

☐ **MT1.01** **SQC2005** – verify, through investigation (e.g., using dynamic geometry software, concrete materials), properties of similar triangles (e.g., given similar triangles, verify the equality of corresponding angles and the proportionality of corresponding sides);

Solving Problems Involving the Trigonometry of Right Triangles

☐ **MT2.01** **SQC2005** – determine, through investigation (e.g., using dynamic geometry software, concrete materials), the relationship between the ratio of two sides in a right triangle and the ratio of the two corresponding sides in a similar right triangle, and define the sine, cosine, and tangent ratios (e.g., sin A = opposite/hypotenuse);

Solving Problems Involving Surface Area and Volume, Using the Imperial and Metric Systems of Measurement

☐ **MT3.03** **SQC2005** – determine, through investigation, the relationship for calculating the surface area of a pyramid (e.g., use the net of a squarebased pyramid to determine that the surface area is the area of the square base plus the areas of the four congruent triangles);

Gr.10 Foundations of Mathematics---Modelling Linear Relations MFM 2P

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Graphing and Writing Equations of Lines

- ☐ **ML2.02** **SQC2005** – identify, through investigation, y = mx + b as a common form for the equation of a straight line, and identify the special cases x = a, y = b;
- ☐ **ML2.03** **SQC2005** – identify, through investigation with technology, the geometric significance of m and b in the equation y = mx + b;
- ☐ **ML2.04** **SQC2005** – identify, through investigation, properties of the slopes of lines and line segments (e.g., direction, positive or negative rate of change, steepness, parallelism), using graphing technology to facilitate investigations, where appropriate;

Gr.10 Foundations of Mathematics---Quadratic Relations of the Form y = ax2 + bx + c MFM 2P

Identifying Characteristics of Quadratic Relations

- ☐ **QR2.02** **SQC2005** – determine, through investigation using technology, that a quadratic relation of the form $y = ax^2 + bx + c$ (a not equal to 0) can be graphically represented as a parabola, and determine that the table of values yields a constant second difference (Sample problem: Graph the quadratic relation $y = x^2 – 4$, using technology. Observe the shape of the graph. Consider the corresponding table of values, and calculate the first and second differences. Repeat for a different quadratic relation. Describe your observations and make conclusions.);
- ☐ **QR2.04** **SQC2005** – compare, through investigation using technology, the graphical representations of a quadratic relation in the form $y = x^2 + bx + c$ and the same relation in the factored form y = (x – r)(x – s) (i.e., the graphs are the same), and describe the connections between each algebraic representation and the graph [e.g., the y-intercept is c in the form $y = x^2 + bx + c$; the x-intercepts are r and s in the form y = (x – r)(x – s)] (Sample problem: Use a graphing calculator to compare the graphs of $y = x^2 + 2x – 8$ and y = (x + 4)(x – 2). In what way(s) are the equations related? What information about the graph can you identify by looking at each equation? Make some conclusions from your observations, and check your conclusions with a different quadratic equation.).

Gr.12 Advanced Functions---Mathematics Process Specific Expectations MHF 4U

Problem Solving

- ☐ **MPS.01** **CR2007** • develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

- ☐ **MPS.03** **CR2007** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

- ☐ **MPS.04** **CR2007** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.12 Advanced Functions---A. EXPONENTIAL AND LOGARITHMIC FUNCTIONS MHF 4U

2. Connecting Graphs and Equations of Logarithmic Functions

- ☐ **EL2.01** **CR2007** 2.1 determine, through investigation with technology (e.g., graphing calculator, spreadsheet) and without technology, key features (i.e., vertical and horizontal asymptotes, domain and range, intercepts, increasing/decreasing behaviour) of the graphs of logarithmic functions of the form $f(x) = \log_b x$, and make connections between the algebraic and graphical representations of these logarithmic functions Sample problem: Compare the key features of the graphs of $f(x) = \log_2 x$, $g(x) = \log_4 x$, and $h(x) = \log_8 x$ using graphing technology.

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☐ **EL2.03** **CR2007**
2.3 determine, through investigation using technology, the roles of the parameters d and c in functions of the form $y = \log_{10}(x – d) + c$ and the roles of the parameters a and k in functions of the form $y = a\log_{10}(kx)$, and describe these roles in terms of transformations on the graph of $f(x) = \log_{10}x$ (i.e., vertical and horizontal translations; reflections in the axes; vertical and horizontal stretches and compressions to and from the x-and y-axes) Sample problem: Investigate the graphs of $f(x) = \log_{10}(x) + c$, $f(x) = \log_{10}(x – d)$, $f(x) = a\log_{10} x$, and $f(x) = \log_{10}(kx)$ for various values of c, d, a, and k, using technology, describe the effects of changing these parameters in terms of transformations, and make connections to the transformations of other functions such as polynomial functions, exponential functions, and trigonometric functions.

Gr.12 Advanced Functions---C. POLYNOMIAL AND RATIONAL FUNCTIONS MHF 4U

1. Connecting Graphs and Equations of Polynomial Functions

☐ **PO1.02** **CR2007**
1.2 compare, through investigation using graphing technology, the numeric, graphical, and algebraic representations of polynomial (i.e., linear, quadratic, cubic, quartic) functions (e.g., compare finite differences in tables of values; investigate the effect of the degree of a polynomial function on the shape of its graph and the maximum number of x-intercepts; investigate the effect of varying the sign of the leading coefficient on the end behaviour of the function for very large positive or negative x-values) Sample problem: Investigate the maximum number of x-intercepts for linear, quadratic, cubic, and quartic functions using graphing technology.

☐ **PO1.05** **CR2007**
1.5 make connections, through investigation using graphing technology (e.g., dynamic geometry software), between a polynomial function given in factored form [e.g., $f(x) = 2(x – 3)(x + 2)(x – 1)$] and the x-intercepts of its graph, and sketch the graph of a polynomial function given in factored form using its key features (e.g., by determining intercepts and end behaviour; by locating positive and negative regions using test values between and on either side of the x-intercepts) Sample problem: Investigate, using graphing technology, the x-intercepts and the shapes of the graphs of polynomial functions with one or more repeated factors, for example, $f(x) = (x – 2)(x – 3)$, $f(x) = (x – 2)(x – 2)(x – 3)$, $f(x) = (x – 2)(x – 2)(x – 2)(x – 3)$, and $f(x) = (x + 2)(x + 2)(x – 2)(x – 2)(x – 3)$, by considering whether the factor is repeated an even or an odd number of times. Use your conclusions to sketch $f(x) = (x + 1)(x + 1)(x – 3)(x – 3)$, and verify using technology.

☐ **PO1.06** **CR2007**
1.6 determine, through investigation using technology, the roles of the parameters a, k, d, and c in functions of the form $y = af(k(x – d)) + c$, and describe these roles in terms of transformations on the graphs of $f(x) = x^3$and $f(x) = x^4$ (i.e., vertical and horizontal translations; reflections in the axes; vertical and horizontal stretches and compressions to and from the x-and y-axes) Sample problem: Investigate, using technology, the graph of $f(x) = 2(x – d)^3 + c$ for various values of d and c, and describe the effects of changing d and c in terms of transformations.

☐ **PO1.08** **CR2007**
1.8 determine the equation of the family of polynomial functions with a given set of zeros and of the member of the family that passes through another given point [e.g., a family of polynomial functions of degree 3 with zeros 5, –3, and –2 is defined by the equation $f(x) = k(x – 5)(x + 3)(x + 2)$, where k is a real number, $k \neq 0$; the member of the family that passes through (–1, 24) is $f(x) = –2(x – 5)(x + 3)(x + 2)$] Sample problem: Investigate, using graphing technology, and determine a polynomial function that can be used to model the function $f(x) = \sin x$ over the interval $0 \leq x \leq 2\pi$.

☐ **PO1.09** **CR2007**
1.9 determine, through investigation, and compare the properties of even and odd polynomial functions [e.g., symmetry about the y-axis or the origin; the power of each term; the number of x-intercepts; $f(x) = f(–x)$or $f(–x) = –f(x)$], and determine whether a given polynomial function is even, odd, or neither Sample problem: Investigate numerically, graphically, and algebraically, with and without technology, the conditions under which an even function has an even number of x-intercepts.

2. Connecting Graphs and Equations of Rational Functions

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☐ **PO2.01** **CR2007**
2.1 determine, through investigation with and without technology, key features (i.e., vertical and horizontal asymptotes, domain and range, intercepts, positive/negative intervals, increasing/decreasing intervals) of the graphs of rational functions that are the reciprocals of linear and quadratic functions, and make connections between the algebraic and graphical representations of these rational functions [e.g., make connections between $f(x) = 1/[x^2 – 4]$ and its graph by using graphing technology and by reasoning that there are vertical asymptotes at $x = 2$ and $x = –2$ and a horizontal asymptote at $y = 0$ and that the function maintains the same sign as $f(x) = x^2 – 4]$ Sample problem: Investigate, with technology, the key features of the graphs of families of rational functions of the form $f(x) = 1/(x + n)$, and $f(x) = 1/[x^2 + n]$ where n is an integer, and make connections between the equations and key features of the graphs.

☐ **PO2.02** **CR2007**
2.2 determine, through investigation with and without technology, key features (i.e., vertical and horizontal asymptotes, domain and range, intercepts, positive/negative intervals, increasing/decreasing intervals) of the graphs of rational functions that have linear expressions in the numerator and denominator [e.g., $f(x) = 2x/[x– 3]$, $h(x) = x – 2/(3x + 4)$], and make connections between the algebraic and graphical representations of these rational functions Sample problem: Investigate, using graphing technology, key features of the graphs of the family of rational functions of the form $f(x) = 8x/(nx + 1)$ for n = 1, 2, 4, and 8, and make connections between the equations and the asymptotes.

3. Solving Polynomial and Rational Equations

☐ **PO3.01** **CR2007**
3.1 make connections, through investigation using technology (e.g., computer algebra systems), between the polynomial function f(x), the divisor x – a, the remainder from the division $f(x)/[x – a]$, and f(a) to verify the remainder theorem and the factor theorem Sample problem: Divide $f(x) = x^4 + 4x^3 – x^2 – 16x – 14$ by x – a for various integral values of a using a computer algebra system. Compare the remainder from each division with f(a).

☐ **PO3.03** **CR2007**
3.3 determine, through investigation using technology (e.g., graphing calculator, computer algebra systems), the connection between the real roots of a polynomial equation and the x-intercepts of the graph of the corresponding polynomial function, and describe this connection [e.g., the real roots of the equation $x^4 – 13x^2 + 36 = 0$ are the x-intercepts of the graph of $f(x) = x^4 – 13x^2 + 36$] Sample problem: Describe the relationship between the x-intercepts of the graphs of linear and quadratic functions and the real roots of the corresponding equations. Investigate, using technology, whether this relationship exists for polynomial functions of higher degree.

☐ **PO3.05** **CR2007**
3.5 determine, through investigation using technology (e.g., graphing calculator, computer algebra systems), the connection between the real roots of a rational equation and the x-intercepts of the graph of the corresponding rational function, and describe this connection [e.g., the real root of the equation $(x – 2)/(x – 3) = 0$ is 2, which is the x-intercept of the function $f(x) = (x – 2)/(x – 3)$; the equation $1/(x – 3) = 0$ has no real roots, and the function $f(x) = 1/(x – 3)$ does not intersect the x-axis]

Gr.12 Advanced Functions---D. CHARACTERISTICS OF FUNCTIONS MHF 4U

1. Understanding Rates of Change

☐ **CF1.06** **CR2007**
1.6 determine, through investigation using various representations of relationships (e.g., tables of values, graphs, equations), approximate instantaneous rates of change arising from real-world applications (e.g., in the natural, physical, and social sciences) by using average rates of change and reducing the interval over which the average rate of change is determined Sample problem: The distance, d metres, travelled by a falling object in t seconds is represented by $d = 5t^2$. When t = 3, the instantaneous speed of the object is 30 m/s. Compare the average speeds over different time intervals starting at t = 3 with the instantaneous speed when t = 3. Use your observations to select an interval that can be used to provide a good approximation of the instantaneous speed at t = 3.

☐ **CF1.07** **CR2007**
1.7 make connections, through investigation, between the slope of a secant on the graph of a function (e.g., quadratic, exponential, sinusoidal) and the average rate of change of the function over an interval, and between the slope of the tangent to a point on the graph of a function and the instantaneous rate of change of the function at that point Sample problem: Use tangents to investigate the behaviour of a function when the instantaneous rate of change is zero, positive, or negative.

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within: **Mathematics**

☐ **CF1.08** **CR2007** 1.8 determine, through investigation using a variety of tools and strategies (e.g., using a table of values to calculate slopes of secants or graphing secants and measuring their slopes with technology), the approximate slope of the tangent to a given point on the graph of a function (e.g., quadratic, exponential, sinusoidal) by using the slopes of secants through the given point (e.g., investigating the slopes of secants that approach the tangent at that point more and more closely), and make connections to average and instantaneous rates of change

2. Combining Functions

☐ **CF2.01** **CR2007** 2.1 determine, through investigation using graphing technology, key features (e.g., domain, range, maximum/minimum points, number of zeros) of the graphs of functions created by adding, subtracting, multiplying, or dividing functions [e.g., $f(x) = 2^{-x} \sin 4x$, $g(x) = x^2 + 2^x$, $h(x) = \sin x / \cos x$], and describe factors that affect these properties Sample problem: Investigate the effect of the behaviours of $f(x) = \sin x$, $f(x) = \sin 2x$, and $f(x) = \sin 4x$ on the shape of $f(x) = \sin x + \sin 2x + \sin 4x$.

☐ **CF2.03** **CR2007** 2.3 determine, through investigation, and explain some properties (i.e., odd, even, or neither; increasing/decreasing behaviours) of functions formed by adding, subtracting, multiplying, and dividing general functions [e.g., $f(x) + g(x)$, $f(x)g(x)$] Sample problem: Investigate algebraically, and verify numerically and graphically, whether the product of two functions is even or odd if the two functions are both even or both odd, or if one function is even and the other is odd.

☐ **CF2.08** **CR2007** 2.8 make connections, through investigation using technology, between transformations (i.e., vertical and horizontal translations; reflections in the axes; vertical and horizontal stretches and compressions to and from the x-and y-axes) of simple functions f(x) [e.g., $f(x) = x^3 + 20$, $f(x) = \sin x$, $f(x) = \log x$] and the composition of these functions with a linear function of the form $g(x) = A(x + B)$ Sample problem: Compare the graph of $f(x) = x^2$ with the graphs of $f(g(x))$ and $g(f(x))$, where $g(x) = 2(x - d)$, for various values of d. Describe the effects of d in terms of transformations of f(x).

3. Using Function Models to Solve Problems

☐ **CF3.01** **CR2007** 3.1 compare, through investigation using a variety of tools and strategies (e.g., graphing with technology; comparing algebraic representations; comparing finite differences in tables of values) the characteristics (e.g., key features of the graphs, forms of the equations) of various functions (i.e., polynomial, rational, trigonometric, exponential, logarithmic)

☐ **CF3.03** **CR2007** 3.3 solve problems, using a variety of tools and strategies, including problems arising from real-world applications, by reasoning with functions and by applying concepts and procedures involving functions (e.g., by constructing a function model from data, using the model to determine mathematical results, and interpreting and communicating the results within the context of the problem) Sample problem: The pressure of a car tire with a slow leak is given in the following table of values: Time, t (min)*Pressure, P (kPa)*0*400*5*335*10*295*15*255*20*225*25*195*30*170 Use technology to investigate linear, quadratic, and exponential models for the relationship of the tire pressure and time, and describe how well each model fits the data. Use each model to predict the pressure after 60 min. Which model gives the most realistic answer?

Gr.9 Principles of Mathematics---Mathematical Process Specific Expectations MPM 1D

Problem Solving

☐ **MPS.01** **SQC2005**
- develop, select, apply, and compare a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **MPS.03** **SQC2005**
- demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **MPS.04** **SQC2005**
- select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

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Gr.9 Principles of Mathematics---Number Sense and Algebra MPM 1D

Operating with Exponents

- ☐ **NA1.03** **SQC2005** – derive, through the investigation and examination of patterns, the exponent rules for multiplying and dividing monomials, and apply these rules in expressions involving one and two variables with positive exponents;

Gr.9 Principles of Mathematics---Linear Relationships MPM 1D

Overall Expectations

- ☐ **LRV.01** **SQC2005** • apply data-management techniques to investigate relationships between two variables;

Using Data Management to Investigate

- ☐ **LR1.03** **SQC2005** – design and carry out an investigation or experiment involving relationships between two variables, including the collection and organization of data, using appropriate methods, equipment, and/or technology (e.g., surveying; using measuring tools, scientific probes, the Internet) and techniques (e.g., making tables, drawing graphs) (Sample problem: Design and perform an experiment to measure and record the temperature of ice water in a plastic cup and ice water in a thermal mug over a 30 min period, for the purpose of comparison. What factors might affect the outcome of this experiment? How could you design the experiment to account for them?);
- ☐ **LR1.04** **SQC2005** – describe trends and relationships observed in data, make inferences from data, compare the inferences with hypotheses about the data, and explain any differences between the inferences and the hypotheses (e.g., describe the trend observed in the data. Does a relationship seem to exist? Of what sort? Is the outcome consistent with your hypothesis? Identify and explain any outlying pieces of data. Suggest a formula that relates the variables. How might you vary this experiment to examine other relationships?) (Sample problem: Hypothesize the effect of the length of a pendulum on the time required for the pendulum to make five full swings. Use data to make an inference. Compare the inference with the hypothesis. Are there other relationships you might investigate involving pendulums?).

Understanding Characteristics of Linear Relations

- ☐ **LR2.03** **SQC2005** – identify, through investigation, some properties of linear relations (i.e., numerically, the first difference is a constant, which represents a constant rate of change; graphically, a straight line represents the relation), and apply these properties to determine whether a relation is linear or non-linear;

Gr.9 Principles of Mathematics---Analytic Geometry MPM 1D

Overall Expectations

- ☐ **AGV.02** **SQC2005** • determine, through investigation, the properties of the slope and y-intercept of a linear relation;

Investigating the Relationship Between the Equation of a Relation and the Shape of Its Graph

- ☐ **AG1.01** **SQC2005** – determine, through investigation, the characteristics that distinguish the equation of a straight line from the equations of nonlinear relations (e.g., use a graphing calculator or graphing software to graph a variety of linear and non-linear relations from their equations; classify the relations according to the shapes of their graphs; connect an equation of degree one to a linear relation);
- ☐ **AG1.02** **SQC2005** – identify, through investigation, the equation of a line in any of the forms $y = mx + b$, $Ax + By + C = 0$, $x = a$, $y = b$;

Investigating the Properties of Slope

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FIND RESULTS: 292 expectations were found
containing the term(s): **investigate OR investigation**
within: **Gr.7, Gr.8, Gr.9, Gr.10, Gr.11, Gr.12**
within: **Mathematics**

- ☐ **AG2.01** **SQC2005** – determine, through investigation, various formulas for the slope of a line segment or a line (e.g., m = rise/run, m = the change in y/the change in x or m = $\Delta y/\Delta x$, m =$(y_2 – y_1)/(x_2 – x_1)$), and use the formulas to determine the slope of a line segment or a line;
- ☐ **AG2.02** **SQC2005** – identify, through investigation with technology, the geometric significance of m and b in the equation y = mx + b;
- ☐ **AG2.03** **SQC2005** – determine, through investigation, connections among the representations of a constant rate of change of a linear relation (e.g., the cost of producing a book of photographs is $50, plus $5 per book, so an equation is C = 50 + 5p; a table of values provides the first difference of 5; the rate of change has a value of 5, which is also the slope of the corresponding line; and 5 is the coefficient of the independent variable, p, in this equation);
- ☐ **AG2.04** **SQC2005** – identify, through investigation, properties of the slopes of lines and line segments (e.g., direction, positive or negative rate of change, steepness, parallelism, perpendicularity), using graphing technology to facilitate investigations, where appropriate.

Gr.9 Principles of Mathematics---Measurement and Geometry MPM 1D

Overall Expectations

- ☐ **MGV.01** **SQC2005** • determine, through investigation, the optimal values of various measurements;
- ☐ **MGV.03** **SQC2005** • verify, through investigation facilitated by dynamic geometry software, geometric properties and relationships involving two-dimensional shapes, and apply the results to solving problems.

Investigating the Optimal Value of Measurements

- ☐ **MG1.03** **SQC2005** – identify, through investigation with a variety of tools (e.g. concrete materials, computer software), the effect of varying the dimensions on the surface area [or volume] of square-based prisms and cylinders, given a fixed volume [or surface area];

Solving Problems Involving Perimeter, Area, Surface Area and Volume

- ☐ **MG2.04** **SQC2005** – develop, through investigation (e.g., using concrete materials), the formulas for the volume of a pyramid, a cone, and a sphere (e.g., use three-dimensional figures to show that the volume of a pyramid [or cone] is 1/3 the volume of a prism [or cylinder] with the same base and height, and therefore that Vpyramid = Vprism/3 or Vpyramid = ((area of base)(height))/3);
- ☐ **MG2.05** **SQC2005** – determine, through investigation, the relationship for calculating the surface area of a pyramid (e.g., use the net of a squarebased pyramid to determine that the surface area is the area of the square base plus the areas of the four congruent triangles);

Investigating and Applying Geometric Relationships

- ☐ **MG3.01** **SQC2005** – determine, through investigation using a variety of tools (e.g., dynamic geometry software, concrete materials), and describe the properties and relationships of the interior and exterior angles of triangles, quadrilaterals, and other polygons, and apply the results to problems involving the angles of polygons (Sample problem:With the assistance of dynamic geometry software, determine the relationship between the sum of the interior angles of a polygon and the number of sides. Use your conclusion to determine the sum of the interior angles of a 20-sided polygon.);
- ☐ **MG3.02** **SQC2005** – determine, through investigation using a variety of tools (e.g., dynamic geometry software, paper folding), and describe some properties of polygons (e.g., the figure that results from joining the midpoints of the sides of a quadrilateral is a parallelogram; the diagonals of a rectangle bisect each other; the line segment joining the midpoints of two sides of a triangle is half the length of the third side), and apply the results in problem solving (e.g., given the width of the base of an A-frame tree house, determine the length of a horizontal support beam that is attached half way up the sloping sides);
- ☐ **MG3.03** **SQC2005** – pose questions about geometric relationships, investigate them, and present their findings, using a variety of mathematical forms (e.g., written explanations, diagrams, dynamic sketches, formulas, tables) (Sample problem: How many diagonals can be drawn from one vertex of a 20-sided polygon? How can I find out without counting them?);

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within: **Mathematics**

Gr.9 Mathematics Transfer---Mathematics Process Specific Expectations MPM 1H

Problem Solving

☐ **MPS.01** **CR2006** • develop, select, apply, compare, and adapt a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

☐ **MPS.03** **CR2006** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

☐ **MPS.04** **CR2006** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

Gr.9 Mathematics Transfer---Number Sense and Algebra MPM 1H

Operating with Exponents

☐ **NS1.01** **CR2006** – derive, through the investigation and examination of patterns, the exponent rules for multiplying and dividing monomials, and apply these rules in expressions involving one and two variables with positive exponents;

Gr.9 Mathematics Transfer---Analytic Geometry MPM 1H

Overall Expectations

☐ **AGV.03** **CR2006** • determine, through investigation, the properties of the slope and y-intercept of a linear relation;

Understanding Characteristics of Linear Relations

☐ **AG1.01** **CR2006** – design and carry out an investigation or experiment involving relationships between two variables, including the collection and organization of data, using appropriate methods, equipment, and/or technology (e.g., surveying; using measuring tools, scientific probes, the Internet) and techniques (e.g.,making tables, drawing graphs) (Sample problem: Design and perform an experiment to measure and record the temperature of ice water in a plastic cup and ice water in a thermal mug over a 30 min period, for the purpose of comparison. What factors might affect the outcome of this experiment? How could you design the experiment to account for them?);

Investigating the Relationship Between the Equation of a Relation and the Shape of Its Graph

☐ **AG2.01** **CR2006** – determine, through investigation, the characteristics that distinguish the equation of a straight line from the equations of non-linear relations (e.g., use a graphing calculator or graphing software to graph a variety of linear and non-linear relations from their equations; classify the relations according to the shapes of their graphs; connect an equation of degree one to a linear relation);

☐ **AG2.02** **CR2006** – identify, through investigation, the equation of a line in any of the forms y = mx + b, Ax + By + C = 0, x = a, y = b;

Investigating the Properties of Slope

☐ **AG3.01** **CR2006** – determine, through investigation, various formulas for the slope of a line segment or a line (e.g., m = [rise/run]; m = [the change in y/the change in x] or m = $\Delta y/\Delta x$, m = $[y_2 - y_1/x_2 - x_1]$), and use the formulas to determine the slope of a line segment or a line;

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- ☐ **AG3.02** **CR2006** – identify, through investigation with technology, the geometric significance of m and b in the equation y = mx + b;
- ☐ **AG3.03** **CR2006** – determine, through investigation, connections between slope and other representations of a constant rate of change of a linear relation (e.g., if the cost of producing a book of photographs is $50, plus $5 per book, then the slope of the line that represents the cost versus the number of books produced has a value of 5, which is also the rate of change; the value of the slope is the value of the coefficient of the independent variable in the equation of the line, C = 50 + 5p, and the value of the first difference in a table of values);
- ☐ **AG3.04** **CR2006** – identify, through investigation, properties of the slopes of lines and line segments (e.g., direction, positive or negative rate of change, steepness, parallelism, perpendicularity), using graphing technology to facilitate investigations, where appropriate.

Gr.9 Mathematics Transfer---Measurement and Geometry MPM 1H

Overall Expectations

- ☐ **MGV.02** **CR2006** • verify, through investigation facilitated by dynamic geometry software, geometric properties and relationships involving two-dimensional shapes, and apply the results to solving problems.

Solving Problems Involving Surface Area and Volume

- ☐ **MG1.02** **CR2006** – determine, through investigation, the relationship for calculating the surface area of a pyramid (e.g., use the net of a squarebased pyramid to determine that the surface area is the area of the square base plus the areas of the four congruent triangles);
- ☐ **MG1.04** **CR2006** – identify, through investigation with a variety of tools (e.g. concrete materials, computer software), the effect of varying the dimensions on the surface area [or volume] of square-based prisms and cylinders, given a fixed volume [or surface area];

Investigating and Applying Geometric Relationships

- ☐ **MG2.01** **CR2006** – determine, through investigation using a variety of tools (e.g., dynamic geometry software, paper folding), and describe some properties of polygons (e.g., the figure that results from joining the midpoints of the sides of a quadrilateral is a parallelogram; the diagonals of a rectangle bisect each other; the line segment joining the midpoints of two sides of a triangle is half the length of the third side), and apply the results in problem solving (e.g., given the width of the base of an A-frame tree house, determine the length of a horizontal support beam that is attached half way up the sloping sides);
- ☐ **MG2.02** **CR2006** – pose questions about geometric relationships, investigate them, and present their findings, using a variety of mathematical forms (e.g., written explanations, diagrams, dynamic sketches, formulas, tables) (Sample problem: How many diagonals can be drawn from one vertex of a 20- sided polygon? How can I find out without counting them?);

Gr.10 Principles of Mathematics---Mathematical Process Specific Expectations MPM 2D

Problem Solving

- ☐ **MPS.01** **SQC2005** • develop, select, apply, and compare a variety of problem-solving strategies as they pose and solve problems and conduct investigations, to help deepen their mathematical understanding;

Reflecting

- ☐ **MPS.03** **SQC2005** • demonstrate that they are reflecting on and monitoring their thinking to help clarify their understanding as they complete an investigation or solve a problem (e.g., by assessing the effectiveness of strategies and processes used, by proposing alternative approaches, by judging the reasonableness of results, by verifying solutions);

Selecting Tools and Computational Strategies

- ☐ **MPS.04** **SQC2005** • select and use a variety of concrete, visual, and electronic learning tools and appropriate computational strategies to investigate mathematical ideas and to solve problems;

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within: **Mathematics**

Gr.10 Principles of Mathematics---Quadratic Relations of the Form y = ax2 + bx + c MPM 2D

Investigating the Basic Properties of Quadratic Relations

- ☐ **QR1.02** **SQC2005** – determine, through investigation with and without the use of technology, that a quadratic relation of the form $y = ax^2 + bx + c$ (a not equal to 0) can be graphically represented as a parabola, and that the table of values yields a constant second difference (Sample problem: Graph the relation $y = x^2 – 4x$ by developing a table of values and plotting points. Observe the shape of the graph. Calculate first and second differences. Repeat for different quadratic relations. Describe your observations and make conclusions, using the appropriate terminology.);
- ☐ **QR1.04** **SQC2005** – compare, through investigation using technology, the features of the graph of $y = x^2$ and the graph of $y = 2^x$, and determine the meaning of a negative exponent and of zero as an exponent (e.g., by examining patterns in a table of values for $y = 2^x$; by applying the exponent rules for multiplication and division).

Relating the Graph of $y = x^2$ and Its Transformations

- ☐ **QR2.01** **SQC2005** – identify, through investigation using technology, the effect on the graph of $y = x^2$ of transformations (i.e., translations, reflections in the x-axis, vertical stretches or compressions) by considering separately each parameter a, h, and k [i.e., investigate the effect on the graph of $y = x^2$ of a, h, and k in $y = x^2 + k$, $y = (x – h)^2$, and $y = ax^2$];

Solving Quadratic Equations

- ☐ **QR3.03** **SQC2005** – determine, through investigation, and describe the connection between the factors of a quadratic expression and the x-intercepts (i.e., the zeros) of the graph of the corresponding quadratic relation, expressed in the form $y = a(x – r)(x – s)$;
- ☐ **QR3.04** **SQC2005** – interpret real and non-real roots of quadratic equations, through investigation using graphing technology, and relate the roots to the x-intercepts of the corresponding relations;

Gr.10 Principles of Mathematics---Analytic Geometry MPM 2D

Using Analytic Geometry to Verify Geometric Properties

- ☐ **AG3.01** **SQC2005** – determine, through investigation (e.g., using dynamic geometry software, by paper folding), some characteristics and properties of geometric figures (e.g., medians in a triangle, similar figures constructed on the sides of a right triangle);

Gr.10 Principles of Mathematics---Trigonometry MPM 2D

Overall Expectations

- ☐ **TRV.01** **SQC2005** • use their knowledge of ratio and proportion to investigate similar triangles and solve problems related to similarity;

Investigating Similarity and Solving Problems Involving Similar Triangles

- ☐ **TR1.01** **SQC2005** – verify, through investigation (e.g., using dynamic geometry software, concrete materials), the properties of similar triangles (e.g., given similar triangles, verify the equality of corresponding angles and the proportionality of corresponding sides);

Solving Problems Involving the Trigonometry of Right Triangles

- ☐ **TR2.01** **SQC2005** – determine, through investigation (e.g., using dynamic geometry software, concrete materials), the relationship between the ratio of two sides in a right triangle and the ratio of the two corresponding sides in a similar right triangle, and define the sine, cosine, and tangent ratios (e.g., sin A = opposite/hypotenuse);